1997 RAC and



CRUMB RUBBER PRODUCTS WORKSHOPS

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MAY 23, 1997 Monterey Beach Bay View Hotel

MAY 30, 1997
Sheraton Anaheim Hotel

genda

1997 RAC AND CRUMB RUBBER PRODUCTS WORKSHOPS

MONTEREY

MAY 22, 1997

5:00 p.m. - 6:00 p.m.

No-Host Reception and Pre-Registration

MAY 23, 1997

8:00 a.m. - 9:00 a.m.

Continental Breakfast and Registration

9:00 a.m. - 9:45 a.m.

General Session

Moderator:

Michael Frost, City of Folsom

Speakers:

Ralph Chandler, California Integrated Waste Management Board

Joe Divinagracia, Clean Washington Center

9:45 a.m. - 10:00 a.m.

Break

10:00 a.m. - 12:00 p.m.

Track I: Crumb Rubber Products

Moderator: Speakers:

Robert Feinbaum, Feinbaum Associates Ethan Grove, Elastomeric Technologies, Inc.

Cornelia Snyder, JaiTire Industries, Inc.

Track II: Rubberized Asphalt Concrete

Moderator:

Jack Van Kirk, Caltrans

Speakers:

Cliff Ashcroft, Manhole Adjusting Contractors, Inc.

Gary Hildebrand, Caltrans

Ross Kashiwagi, Granite Construction

David Strassman, DRS Ltd. lack Van Kirk, Caltrans

12:00 p.m. - 1:30 p.m.

Luncheon

Keynote

Speaker:

John Serumgard, Scrap Tire Management Council

1:30 p.m. - 3:30 p.m.

Track I: Crumb Rubber Products

Moderator:

Robert Feinbaum, Feinbaum Associates Frank Congemi, American Rubbertech

Speakers: Richard Posiviata, Environmental Molding Concepts

Paul Schubring, Carsonite International

Peter Spendlove, Sports Advancement and Research Co. Ltd.

Track II: Rubberized Asphalt Concrete

Moderator:

Jack Van Kirk, Caltrans

Speakers:

Joe Goldhammer, San Diego County Materials Testing Lab

Mike Harrington, BAS Recycling, Inc.

Tom Kirk, Willdan Associates

Frank Lancaster, Los Angeles County Department of Public Works

Barry Takallou, TAK Consulting Engineers

3:30 p.m. - 3:45 p.m.

Break

3:45 p.m. - 4:30 p.m.

General Session for Wrap-Up

Moderator:

Michael Frost, City of Folsom

Welcome To The 1997 RAC And Crumb Rubber Products Workshops

Dear Conference Attendee:

As manager of the recycling component of the California
Integrated Waste Management Board's Tire Program, I am pleased
to welcome you to the 1997 Rubberized Asphalt Concrete and Crumb
Rubber Products Workshops. These workshops have been designed
to provide participants with the information needed for making
sound decisions regarding the purchase of products containing
crumb rubber. Panel members from both recycling businesses and
local governments are here to provide you with information on
available products, the benefits of their use, and examples of their
successful applications.

Please don't hesitate to ask any questions of panel members or CIWMB staff. Thank you for your interest and participation in "closing-the-loop" on tire recycling. I hope you benefit from the workshop.

Martha Gildart Branch Manager CIWMB

Martha Gildart

Agenda

1997 RAC AND CRUMB RUBBER PRODUCTS WORKSHOPS

ANAHEIM

MAY 29, 1997

5:00 p.m. - 6:00 p.m.

No-Host Reception and Pre-Registration

MAY 30, 1997

8:00 a.m. - 9:00 a.m.

Continental Breakfast and Registration

9:00 a.m. - 9:45 a.m.

General Session

Introductions:

Robert Frazee, California Integrated Waste Management Board

Moderator: Speaker:

John Serumgard, Scrap Tire Management Council

Mary Sikora, Recycling Research Institute

9:45 a.m. - 10:00 a.m.

Break

10:00 a.m. - 12:00 p.m.

Track I: Crumb Rubber Products

Moderator: Speakers:

Ann Baba, Ann Baba Associates
Frank Congemi, American Rubbertech

Cornelia Snyder, JaiTire Industries, Inc.

Track II: Rubberized Asphalt Concrete

Moderator:

Kelly McArthur Ingalls, City of Los Angeles,

Integrated Solid Waste Management

Speakers:

Cliff Ashcroft, Manhole Adjusting Contractors, Inc.

Mike Harrington, BAS Recycling, Inc.

Gary Hildebrand, Caltrans

Ross Kashiwagi, Granite Construction

Jack Van Kirk, Caltrans

12:00 p.m. - 1:30 p.m.

Luncheon

Keynote

Speaker:

Mary Sikora, Recycling Research Institute

1:30 p.m. - 3:30 p.m.

Track I: Crumb Rubber Products

Moderator:

Ann Baba, Ann Baba Associates

Speakers:

Tom Pickard, Bayley Products LLC

Richard Posiviata, Environmental Molding Concepts

Paul Schubring, Carsonite International

Track II: Rubberized Asphalt Concrete

Moderator:

Kelly McArthur Ingalls, City of Los Angeles,

Integrated Solid Waste Management

Speakers:

Joe Goldhammer, San Diego County Materials Testing Lab

Tom Kirk, Willdan Associates

Frank Lancaster, Los Angeles County Department of Public Works

Barry Takallou, TAK Consulting Engineers

3:30 p.m. - 3:45 p.m.

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3:45 p.m. - 4:30 p.m.

General Session for Wrap-Up

Moderator:

Mary Sikora, Recycling Research Institute

Keynote Speakers

Ralph Chandler, Executive Director,

California Integrated Waste Management Board

Raiph Chandler has been the Executive Director for the California Integrated Waste Management Board since June 1991. Mr. Chandler served as Chief of the Division of Recycling at the California Department of Conservation from 1989 through May 1991. In that position, he oversaw a \$285 million recycling program and a staff of 175. He had been with the state's beverage container recycling program since its inception in 1986. In his first position with the division as Manager of Certification, he was responsible for developing regulations and guidelines for recyclers, processors, and recycling programs. In 1988, Mr. Chandler became the Deputy Chief in charge of ensuring fiscal oversight of the program and was responsible for implementing the state's glass and plastic beverage container processing fees — fees paid by container manufacturers to cover recycling costs in excess of the containers' scrap value. From 1981 to 1986, Mr. Chandler was with the California Energy Commission, managing its Research and Development Office. There, he supervised 20 technical staff and administered over \$10 million in research and development loan programs annually. Prior to that, he was the Project Manager for the Commission's Biomass Demonstration Program, which assisted agricultural and forestry industries in substituting waste residues for conventional energy sources. Mr. Chandler received a Bachelors degree in Economics and Business Management from U.C. Davis in 1974. He has also published several professional papers in the field of alternative energy resources and recycling.

Joe Divinagracia, Materials Engineer,

Clean Washington Center

Mr. Divinagracia's background in materials engineering, particularly working with plastics and rubber materials, has provided the Center the ability to pursue value-added applications for these materials. His expertise with processing and manufacturing equipment enables him to manage diverse projects involving processing and compounding through product manufacturing and testing. Mr. Divinagracia participates in national organizations involved in recycling and serves as a board member for the Society of Plastics Engineers Recycling Division.

Best Practices Manual—Recycled Scrap Tires and Rubber

The Clean Washington Center (CWC), through its Recycling Technology Assistance Partnership (ReTAP), is developing commodity-specific Best Practices Manuals and Best Practices Workshops. These workshops and manuals focus on effective uses of recycled materials and effective application of recycling technologies. The manuals contain summaries of industry practices that maximize the cost and performance advantages of recycled feedstocks.

Robert C. Frazee, Vice Chairman, California Integrated Waste Management Board

Vice Chairman Robert C. Frazee was appointed by Governor Pete Wllson to the California Integrated Waste Management Board as a public representative in 1995. Mr. Frazee chairs the Permitting and Enforcement Committee and is a member of the Legislation and Public Education and the Local Assistance and Planning Committees. Prior to his Board appointment, he represented northern San Diego County in the Assembly from 1978 to 1994. Before Mr. Frazee's election to the Legislature, he served as Mayor and Council Member of Carlsbad. He was also founding chair of the North County Transit District Board, chair of the Regional Coastal Commission, and a member of the SANDER Board, a waste-to-energy project.

Keynote Speakers

Michael Frost, City Manager,

City of Folsom

For the first eight years of Mr. Frost's career, he worked for the Western Pacific Railroad as a Switchman, Switch Engine Foreman, and Yardmaster. He spent four years of this time earning his college degree. His career proceeds as follows:

- Eight years as Chief of Staff to State Senator Fred Marler, Jr.;
- Minority Leader of the California State Senate;
- Appointed by Governor Ronald Reagan as Assistant Secretary of the California State Personnel Board for eight years;
- Appointed by President Ronald Reagan as Associate Director of the Office of Personnel Management in Washington,
 D.C. for two years;
- Returned to California by newly-elected Governor George Deukmejian to become Director of the new Department of Personnel Administration for two years;
- Appointed by Governor Deukmejian as Chairman of the California Integrated Waste Management Board, where he served for three years;
- Governor Wilson appointed him as Acting Secretary of the California Environmental Protection Agency; and
- In 1993, he was named City Manager by the Folsom City Council.

John Serumgard, Chairman,

Scrap Tire Management Council

John Serumgard is Chairman of the Scrap Tire Management Council (STMC). STMC is the only national organization devoted to expanding all markets for scrap tires.

Crumb Rubber and Beyond: A National Perspective

Mary Sikora, Principal,

Recycling Research Institute

Mary Sikora, Principal of Recycling Research Institute, is currently the publisher of Scrap Tire News, a monthly newsletter devoted to promoting responsible, proper, and environmentally sound scrap tire recovery, recycling, and disposal. Ms. Sikora is the author of a 1986 study "Tire Recovery and Disposal: A-National Problem with New Solutions." She has conducted both national and regional seminars devoted to scrap tire issues and has been a frequent speaker at national, international, and regional tire industry conferences, as well as environmental and waste management seminars and expositions. Ms. Sikora currently serves as a scrap tire advisor to the American Retreaders Association. She previously served as Director of Marketing and Public Relations for Consolidated Energy Systems, Inc., was the former Editor of Waste Age magazine, and has more than 12 years' experience in the waste industry.

Tire and Rubber Recycling: An Industry at Work

This presentation will bring you a capsule update on the scrap tire and rubber recycling industry including the emerging trends and market forces that are driving progress. Also, it will show you how tire and rubber recyclers are working to produce new

Crumb Rubber Products

Moderator (Monterey): Robert Feinbaum, President,

Feinbaum Associates

Dr. Robert Feinbaum is the Business Recycling Consultant for the California State Chamber of Commerce and President of Feinbaum Associates. He is a Master Composter, certified by Alameda County, CA, and the author of "The Recycling Handbook" and "The Recycling Organizer for Business." Feinbaum Associates is currently working on a feasibility study for composting source separated food waste in Alameda County. Dr. Feinbaum has served on the faculty of the University of Santa Clara and the University of New Mexico, and holds a Ph.D. in Sociology from the University of California, Berkeley.

Moderator (Anaheim): Ann Baba, Consultant,

Ann Baba Associates

Ann Baba uses her background in business management, education, and public outreach to help businesses increase source reduction and recycling. She has also helped them to quantify solid waste and financial savings from these activities. Ms. Baba has also worked with the CIWMB to develop a formula to measure tire piles, and has surveyed other states on post-consumer uses of tires. Ann Baba Associates has been a Certified Woman/ Minority Business Enterprise by Caltrans and both the City and County of Los Angeles.

Research and Problem-Solving: Researched for national market analysis, city and state agencies, integrating results into their strategies.

Public Outreach: Conducted audio-visual presentations in public and private sectors, community meetings. Acted as liaison between jurisdictions and communities, companies and customers.

Guidance and Consulting: Consulted on goals, and best strategy to reach them with parents and community groups, public agencies and community groups, private companies.

Project Management: Managed projects for jurisdictions' solid waste plans, UCLA Extension recycling research projects.

Accounting and Finance: Performed accounting and finance functions for a small company.

Frank Congemi, President,

American Rubbertech

Mr. Congemi is currently President of American Rubbertech which was started in 1990. He is responsible for creating markets for crumb rubber products. The obstacles include dealing with regulatory issues, storage of crumb rubber, and no uniform Federal Regulatory Code. He has been a licensed security dealer for the last 12 years. He has had zero compliance, zero arbitration, and zero letters of complaint.

Critical Issues Facing the Crumb Rubber Industry Today

Manufacturer's responsibility to the end use of their product and why recycled highway safety products and street furniture make dollars and sense. Regulatory climate for waste tires.

Ethan Grove, President,

Elastomeric Technologies, Inc.

Ethan Grove is a selected member of the Universal Who's Who Publication of Outstanding Business Executives. In 1984, he founded Flex-a-Glas Roofing Systems and applied research and development in Neoprene Asphalt Emulsion, as an industrial roofing product to replace hot tar. The company manufactured the product in Baltimore, MD, from 1984-1994. In 1994, Mr. Grove formed a joint venture with EnviroTech Industries in Dallas, TX, for worldwide marketing. In 1995, he built a new 15,000 sq. ft. plant in Baltimore, MD, to produce 5,000 gallons of the product daily.

Resilient Surfaces and Coatings Made with Latex Neoprene and Recycled Rubber

Application Process Equipment for Paving Surfaces and Spray Systems to Apply Recycled Coatings

Tom Pickard, President,

Bayley Products LLC

Tom Pickard is the President of Bayley Products LLC, a firm specializing in the development and marketing of custom molded and sheet rubber products with industrial applications. He was formally Product Manager, Industrial Products for National Rubber Company, Inc. of Toronto, Canada. National Rubber has developed and manufactured products from reclaimed and recycled rubber for over 60 years. The company is a Tier I supplier to Ford, Chrysler, and GM, and is North America's leading tire recycling company.

Crumb Rubber Products

Developing Profitable Rubber Products: From Scrap to Value-Added

Successful products, derived from crumb rubber compounds, are developed and sold every day. Profitable products can be marketed at a value-added that far exceeds that of rubberized asphalt. This talk will draw from experiences, successes, and failures in the development and marketing of industrial products derived from crumb rubber raw materials. Included will be case studies of various projects conducted in the recreation, packaging, civil engineering, and transportation markets.

Richard Posiviata, General Manager,

EMC - Environmental Molding Concepts

Richard Posiviata is currently Vice President/General Manager of Environmental Molding Concepts. He possesses over 27 years of varied management, technical, and manufacturing experience in the rubber and plastics industry. In 1970, Mr. Posiviata joined Gates Corporation, a world leader in rubber products. While at Gates, he held various positions, including Manager of Materials Research and Engineering and Technical Vice President for Gates Energy Products. He served as Director of Manufacturing Operations and Technical Director of Research and Engineering for American Roller Company, Chicago, Illinois, Vice President of Operations for Briteline and CEO for Fanplastics and Environmed of Nevada. Mr. Posiviata graduated from Southeastern Massachusetts Institute of Technology with a Bachelor of Science degree in Textile Chemistry and Engineering. He has completed the accelerated advanced management course at Harvard Business School, Cambridge, Massachusetts and served on the Board of Directors of the Colorado Advanced Materials Institute.

Beneficial Uses of Crumb Rubber from Whole Tire Recycling

With assistance from the CIWMB, Environmental Molding Concepts has developed a playground surfacing mat, KID KUSION, that is produced from crumb rubber that is 100% derived from whole tire recycling. In addition to being a new market for crumb rubber, this surfacing meets CPSC Standards for a 9' drop height and mobility requirements of ADA. Each two foot by two foot KID KUSION requires the recycling of three waste tires generated in California.

Paul Schubring, National Manager,

Carsonite International

Mr. Schubring is National Manager for New Market Development at Carsonite International. He has worked 25 years with firms serving the transportation market in the United States.

A Sound Solution

The use of post-consumer scrap rubber in noise reduction along highways and railroads.

Cornelia Snyder, President,

JaiTire Industries, Inc.

Ms. Cornelia "Corny" Snyder is President of JaiTire Industries, Inc. JaiTire is a pioneer in developing and marketing new products from recycled tires. JaiTire is committed to finding innovative and practical uses for crumb rubber through its national and international dealer network. Ms. Snyder is a Board Member for the National Recycling Coalition and President of the Colorado Association for Recycling. She is Past President of the Rocky Mountain Inventors and Entrepreneurs Congress.

Looking at Crumb Rubber as a Unique Engineering Material

Crumb rubber is a unique engineering material. Ms. Snyder will enumerate those properties which are unique to recycled tires and look at several high value uses including Crown IIITM top dressing for turf. There are many impressive sites in California, several of which will be highlighted including user comments. JaiTire's 45 dealers nationally and internationally used one percent of the crumb rubber supply last year and expect to use 10 percent of the national production this year.

Peter Spendlove,

Sports Advancement and Research Co. Ltd.

Peter Spendlove is Managing Director of Sports Advancement and Research Company Limited. He has spent 25 years in mainstream architecture, followed by six years in the synthetic sports and construction industry. Mr. Spendlove has worked for a civil engineering company the last two years and conceived and patented the idea in May 1995.

Sureflex Technology

Sureflex is an impact absorbing asphalt which is homogenous in nature and contains a continuous elastic phase, controlled by the viscose nature of the polymer modified bitumen which acts as the binder. The material consists of a block co-polymer bitumen and graded rubber crumb which replaces part of the aggregate and remains intact during the manufacturing process.

Rubberized Asphalt Concrete

Moderator (Monterey): Jack Van Kirk,

Senior Materials and Research Engineer, Caltrans

Mr. Van Kirk is presently Chief of the Flexible Pavement Section in the Pavement Consulting Services Branch. He has worked in the area of materials and research for the past 18 1/2 years at Caltrans. He is a registered Civil Engineer in California. He is also the departmental expert in asphalt concrete (AC), which includes AC mix design, AC pavement recycling, and AC modified mixes. Mr. Van Kirk is one of the leading experts in the U.S. in the subject of rubberized asphalt concrete. He has made presentations on the subject all over the U.S. and other countries.

Moderator (Anaheim): Kelly McArthur Ingalls,

Senior Management Analyst,

City of Los Angeles/Integrated Solid Waste Management

Kelly Ingalls is a Senior Management Analyst with the Integrated Solid Waste Management Office of the City of Los Angeles. His chief assignments include technical assistance to local government and the private sector on waste reduction and recycling; recycled-content products; sustainable design and construction; disaster debris recycling; and waste tire management.

Mr. Ingalls was a member of the City's Waste Tire Task Force, which developed strategies for addressing illegal tire dumping and developing markets for recycled tires and crumb rubber products. He has worked closely with the CIWMB on waste tire recycling program issues.

ISWMO produces a "Tire Re-Use and Recycling Guide," which can be obtained by calling 213/237-0143; sending a fax to 213/847-3054; or via e-mail at ISWMO@loop.com.

CliffAshcroft, Marketing Director,

Manhole Adjusting Contractors Inc.

Cliff Ashcroft is currently General Marketing Manager for the Asphalt-Rubber Paving Division of Manhole Adjusting Contractors Inc. He started his career in the pavement contracting field when he worked with the Equipment Division of Sully Miller in 1984. Later he worked as Manager of Production and Sales at the Norwalk Concrete Plant of Blue Diamond Materials. Prior to joining Manhole Adjusting Contractors Inc., Mr. Ashcroft was the Manager of the Class II Base Department of Blue Diamond in Long Beach. He has been promoting asphalt-rubber to agencies and contractors for nearly 10 years now. He is instrumental in establishing the State of California as a 1,000,000 ton annual consumer (roughly 2,000,000 tires).

Identifying The Key Elements of a Successful Asphalt Rubber Program

Identifying and overcoming obstacles that prohibit the use of rubberized asphalt concrete. An industry perspective of potential pitfalls and key elements to success as identified by the hands-on experience of 10 years in marketing California.

Joe Goldhammer, Materials Engineer, San Diego County Materials Testing Lab

Joe Goldhammer, P.E., G.E., is the Materials Engineer for the San Diego County Department of Public Works, holding that position for the last 20 years. He is responsible for QA/QC of department construction projects, laboratory testing, preliminary soil investigations, development of maintenance strategies, and use of new products.

Use of Crumb Rubber Modified Asphalt Projects in San Diego County

Presents use of crumb rubber modified asphalt cement from the initial crack sealing project in 1977 to current hot mix overlays and chip seals. Discuss projects in solid waste landfill roads, truck routes, residential and commercial roads. In addition, chip seals in the desert will be discussed.

Michael Harrington, Sales and Marketing Director, BAS Recycling, Inc.

Mr. Harrington is a graduate of the University of Washington and spent several years in the aerospace industry and private sector before becoming involved in the asphalt rubber and waste tire industry. In 1985, he became President of PaveTech Corporation which held a proprietary license for one of the systems of incorporating crumb rubber into asphalt concrete. In 1989, he joined BAS Recycling, Inc., a whole tire recycling company located in Southern California. Currently, Mr. Harrington is the Sales and Marketing Director of BAS where he procures markets and sells the 30 million pounds of crumb rubber that BAS produces annually.

Presentation

The use of asphalt rubber concrete offers the opportunity of an improved highway surfacing material with a definite ecological benefit. BAS Recycling is a recycler of whole used tires into crumb rubber that meets the gradation and specification requirements of the Crumb Rubber Modifier (CRM). As evaluations on the use of AR for its enhanced performances are conducted, its ecological benefit should also be included in the evaluations.

Rubberized Asphalt Concrete

Gary Hildebrand, Maintenance Manager,

Caltrans

Gary Hildebrand is a Maintenance Manager for Caltrans and has been with that department over 29 years. His background in Highway Maintenance include working in Districts 1, 4, 7, 10, Headquarters Maintenance, and at the Translab in Sacramento. Prior to his current assignment, Mr. Hildebrand worked in Headquarters Maintenance as a Roadbed Major Maintenance Coordinator. Currently, Mr. Hildebrand works in the Pavement Consulting Services Branch as a consultant to both Caltrans and private industry for all maintenance strategies statewide.

Caltrans' Experience with Asphalt Rubber Chip Seals

Caltrans has been using Asphalt Rubber Chip Seals in their maintenance program since the early 1970's. Caltrans is the leader in the U.S. using the wet process asphalt rubber binder which utilizes scrap tires.

Tom Kirk, Supervising Engineer, Willdan Associates

Tom Kirk, Supervising Engineer, has served as Pavement Engineer for numerous projects over the past twelve years with Willdan Associates. Mr. Kirk's total experience with pavement technology exceeds seventeen years, as Construction Coordinator in City of Industry and Director of Public Works in Sierra Madre. His continuous involvement in pavement management systems and pavement rehabilitation design keeps him up-to-date with the latest developments in the industry. He was the Pavement Engineer on the first asphalt-rubber hot mix overlay on an arterial street in Southern California and performed the same services on over 30 such projects since. As Pavement Engineer, Mr. Kirk prepares specifications, develops structural sections, manages construction inspection and performs asphalt-rubber plant inspections for all of his projects.

The Reaction of Asphalt and Rubber

Attaining a complete reaction of asphalt and crumb rubber for asphalt-rubber pavement binder. Discussion of the nature of and what constitutes a full reaction and how to verify completion of the process, for formulations of the various types of natural rubber and equipment.

Frank Lancaster,

Los Angeles County Department of Public Works

Frank Lancaster graduated from the University of Arizona, Tucson, in 1966. He began his career with the Los Angeles County Road Department in June of 1966, where he gained a wide background in highway engineering, including experience in highway design, traffic signal design, construction, and materials engineering. Mr. Lancaster has been very active in the APWA-AGC Greenbook specification since 1984, and was instrumental in writing the first Greenbook specification for asphalt rubber in 1986. He is active in the Association of Asphalt Paving Technologists (AAPT), the Pacific Coast Conference for Asphalt Specifications, the Asphalt Paving Association, and is Secretary of the Greenbook Committee and Chairman of the Southern Counties Materials Engineers Group.

Presentation

Caltrans guidelines for reduced thickness design of ARHM. Validation of Caltrans guidelines by Los Angeles County:

• Los Angeles County Asphalt Rubber Program overview and case histories.

Asphalt Rubber laydown techniques:

- Density problems,
- · Tracking problems, and
- Tips.

David Strassman, President and General Manager, DRS Ltd.

In 1983, Mr. Strassman purchased and constructed an asphalt plant and is currently one of three producer contractors in the City of Madison. Many of the improvements to DRS Ltd. include adding an asphalt recycle system, converting the plant to produce rubberized asphalt, automating the plant to run on computer, adding a fiber input machine tied to the computer, receiving the U.S. Patent for dry type rubberized asphalt, installing over 25,000 tons of rubberized asphalt, and introducing rubberized streetprint and infrared printing.

It's Easy

Production of rubberized asphalt, installation and lay down procedures, multiple types of applications and recycling capabilities. We have been manufacturing and installing recycled rubberized asphalt for six years now. We currently hold a U.S. patent for dry type procedures, have developed and built all machinery to process rubber and automated batch plant with computerized controls and memory.

Rubberized Asphalt Concrete

Barry Takallou, Vice President,

TAK Consulting Engineers

Dr. Takallou is a nationally and internationally recognized expert in the field of rubber modified asphalt. He has served as co-Principal Investigator on evaluation of rubber modified asphalt for the Alaska and Florida Departments of Transportation. He has developed asphalt rubber (TAK System) specifications, construction guidelines, quality control, and mix design methods for the states of New York, New Jersey, Illinois, Oregon, and Canada. He served as Technical Advisor and Reviewer for the EPA'S Market Development Study for Used Tires.

Applicability of SuperPave Models for Design and Construction of Rubberized Asphalt Pavements

In this presentation, the applicability of SuperPave testing methods for development of mix design and evaluation of rubberized asphalt mix properties, mix designs using both the SHRP Level I and II mix design procedures as well as the traditional Marshall Mix design scheme, and performance testing on the mixtures using the SuperPave Repetitive Simple Shear Test at Constant Height (RSST-CH) to evaluate the resistance to permanent deformation (rutting) of the rubberized asphalt mixtures will be discussed.

The test results indicate that (1) SuperPave mix design resulted in asphalt rubber contents that are significantly higher than values used successfully in the field, (2) Marshall used gyratory compaction could not produce same densification trends, and (3) SuperPave mixture analysis testing (Level II) was used successfully for rubberized asphalt mixtures. Results clearly indicated that mixture selected show acceptable rutting and fatigue behavior for a typical new construction and for overlay design. However, few problems were encountered in running the SuperPave models. The presentation will summarize the results of tests performed on rubberized asphalt binder and mixtures using SuperPave technology and describe the performance of the rubberized asphalt project constructed in Southern California using SuperPave mix design.

Jack Van Kirk, Senior Materials and Research Engineer, Caltrans

Mr. Van Kirk is presently Chief of the Flexible Pavement Section in the Pavement Consulting Services Branch. He has worked in the area of materials and research for the past 18 1/2 years at Caltrans. He is a registered Civil Engineer in California. He is also the departmental expert in asphalt concrete (AC), which includes AC mix design, AC pavement recycling, and AC modified mixes. Mr. Van Kirk is one of the leading experts in the U.S. in the subject of rubberized asphalt concrete. He has made presentations on the subject all over the U.S. and other countries.

Caltrans Pavement Rehabilitation Using Rubberized Asphalt Concrete

Caltrans has considerable experience with the use of recycled rubber in asphalt concrete (AC). This experience began in 1978 and has continued to the present. The experience to date has shown that the use of rubber in asphalt concrete can be cost-effective.

On the early projects, Caltrans compared equal thicknesses of rubberized asphalt concrete (RAC) to conventional AC. The RAC has outperformed the conventional mixes on these projects and most of these projects are still in service. In 1983, a project was constructed using reduced thickness RAC (as compared to the design thickness for the conventional AC). This project has shown that thinner sections of RAC can outperform thicker sections of conventional AC.

In February 1992, Caltrans developed an Interim Design Guide for RAC. This design guide, which was approved by FHWA, allows routine usage of RAC as an approved rehabilitation strategy for pavements in California. Since this guide was approved, the use of RAC has significantly increased in California. However, in 1993 and 1994, there were complaints of illness by workers on Caltrans projects. Caltrans has conducted air emissions testing on over 15 projects beginning in 1993. Testing to date has shown that acceptable worker exposure levels have not been exceeded on these projects. Caltrans is working with industry via a permanent standing committee to improve and refine the RAC specifications.

Speaker Addresses

Cliff Ashcroft

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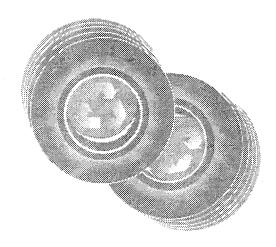
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PRESENTATION MATERIALS Keynote Speakers

JOHN SERUMGARD

Scrap Tire Management Council

Crumb Rubber and Beyond: A National Perspective

Scrap Tire Management Council John Serumgard

Scrap Tire Management Council

- Supported by North American Tire Industry
- **Economically Sound Markets for Scrap** Promotes Environmentally and Tires
- Goal: Markets for 110% of New Scrap Tires

Scrap Tire/Rubber Markets

- Major Markets
- Fuel
- Civil Engineering
- Ground Rubber/Fabricated Products
- Other Markets
- Export
- Agriculture/Miscellaneous

Scrap Tire Generation/Stock Piles

- Annual Generation: 266 million units
- Weight: 3.3 million tons
- Will grow at rate of new tire sales
- Stock piles
- 800 million units
- Many states aggressively reducing stockpiles

Other Scrap Rubber Generation

- Factory Scrap
- 170,000 tons
- Post-consumer
- Automotive
- Roofing
- Other

Growth in Scrap Tire Markets

11 % of Annual Generation **1990**:

▶ 1992: 38 %

• 1994: 56 %

•1995: 69 %

•1996:> 75 %

Tire Derived Fuel Markets

- Capacity at 1/1/97: 152.5 million units
- Operating facilities: 106 locations
- Current issues:
- Greater public awareness/concern
- New EPA PM 2.5 Standard
- Other Clean Air Act Requirements
- Adequate tire supply
- TDF quality
- ASTM specifications (in development)

Tire Derived Fuel Markets

• Cement & Lime Kilns

• Pulp & Paper Mills

• Electrical Generation

Industrial Facilities

Other: WTE, TTE

Civil Engineering Applications

- Estimated 1996 usage: 10 million units
- Reduction from 1996
- Major issue: Washington heating incidents
- AD Hoc Committee
- Guidelines for Thin Fill Applications
- Possible advanced research
- ASTM D34.15 Guidelines

Ground Rubber/Fabricated Products

- Cut, Punched, Stamped Products
- Steady market: 8 million units
- Major issue: Decline in bias ply tire supply
- Ground Rubber
- Total market:

- 400 million pounds
- Whole tire reduction: 12.5 million units
- Market growth: 15 20 % annually

Ground Rubber: Current Issues

- ASTM D11.26 Specifications
- ASTM D 5603-96 Classification
- ASTM D 5644-96 Test method
- RAC Specifications
- **▶** CBOT Recycables Exchange
- Standards
- Market over capacity
- 120 producers

Ground Rubber: Future

- Auto industry requirements
- New technology
- Surface modification, etc.
- New markets
- Playground
- Turf top dressing

Scrap Tire & Rubber Markets: Conclusions

- Industry is growing more mature
- Many state regulatory systems working
- Industry participants gaining experience
- ▶ BUT: Profitability difficult, progress not uniform
- Markets are continuing to expand
- All should grow

Market Recap: 1-1-97

- Fuel use
- Size reduced
- Cut, punched
- Civil engineering
- Export
- Ag/misc
- **■** TOTAL

- 152.5 million
- 12.5 million
- 8.0 million
- 10.0 million
- 15.0 million
- 4.0 million
- 202.0 million

PRESENTATION MATERIALS Crumb Rubber Products

entan Grove

Elastomeric Technologies, Inc.

ELASTOMERIC TECHNOLOGIES INC. 6411 Horseshoe Road Clinton, Maryland 20735

HISTORY: In 1984, I founded Flex-A-Glas Roofing Systems, Inc., located in Baltimore, Maryland. The corporation was an applied research and development endeavor. The purpose was to find uses for rubber crumb as a filler or aggregate in latex products. That same year I was introduced to latex neoprene at Dupont laboratories in Wilmington, Delaware. Neoprene is a sensitive product to deal with. I had been informed that industries from Germany were purchasing neoprene for years to use with asphalt emulsions for roofing. However, Dupont could not find an emulsion that was compatible with neoprene. After an exhaustive research, I found a company which was producing an emulsion adhesive that was compatible with neoprene. Manufacturing and sales of this new product was started in 1984. After one year of testing on actual roofs, we were given the green light for production. There was no cracking as is often found in hot asphalt. Deterioration was in the form of slow oxidation. In 1985, commercial industrial roofing sales started. After 13 years of producing and applying this product, our roofs are still in excellent condition.

1987 - The first application of rubber crumb as an aggregate in our roofing product, 20 mesh whole tire rubber crumb was successfully mixed with neoprene asphalt emulsion in the amount of two lb. per gallon emulsion. After months of equipment application failures, the secret of spraying was found. We have since developed an application rate of 5,000 sq. ft. per hr. The crumb rubber has the same gravity in solution as our emulsion. Long-term shelf life is a reality. Minor stirrings brings it back in solution. The result is thicker applications, longer wear surfaces and durability.

1994 - A joint venture was formed with Envirotech Industries and Flex-A-Glas Roofing Systems, Inc. A new corporation was formed. Automated computer controlled machinery was installed to manufacture our asphalt emulsion and neoprene asphalt emulsion crumb rubber product at the rate of 5000 gallons per day.

The new Corporation is known as Enviroflex Manufacturing L.L.C. 1947 Ben Hill Avenue, Baltimore, Maryland 21226.

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The new Corporation is known as Enviroflex Manufacturing L.L.C. 1947 Ben Hill Avenue, Baltimore, Maryland 21226. 1995 - Upon submittal of our neoprene asphalt crumb rubber membrane to Underwriters Laboratories (UL) for flame spread test, we sought and received a Class A rating which gave us the opportunity to use the material on schools and public buildings. It is light weight, environmentally friendly, has no fumes, and is fireproof and easily maintainable.

1996 - 1997 The products are now marketed by Envirotech Industries, Inc., 9420 W. Lake Highlands Drive, Dallas, Texas 75218. (Voice) 214-327-3904. (Fax)214-327-4713.

Elastomeric Technologies, Inc., 6411 Horseshoe Road, Clinton, Maryland 20735 (Voice) 800-680-9995. (Fax 301-868-4822.)

Following are some of the other uses for recycled crumb:

PLAYGROUND TWO INCH THICK MATS. After five years of research and development, a final testing was completed by US Testing Laboratories. At two inch thick, the mats are A.S.T.M. certified for a head fall test of 5'6" in two areas of tests (Hick and Ram). They exceed requirements by 20%. These mats utilize 5lb. of 1/8" rubber crumb per sq. ft. of area. 1.50 lb. of Neoprene mat binder. The manufacturing process machinery is fully developed and waiting for a manufacturing organization to promote them into the market place. Business plans and financial aids are available to qualified parties.

MINI PAVER: As latex binders were developed to utilize crumb rubber for playground and running tracks for resilient surfaces, it opened the door for a machine to mix the rubber crumb and binder along with a catalyst to cure it and apply it to the surface at 1/4" thickness. This patent applied for machine is fully developed and ready to go to work. The Mini Paver can install 2400 sq. ft. per hour or 19,200 sq. ft. per day.

SPRAY SYSTEMS: In 1995, the first successful spray application of E-Flex 2 was applied to a 30,000 sq. ft. roof for Dupont in Louisville, Kentucky. Our roofing formula of neoprene asphalt emulsion and 20 mesh rubber crumb was applied using a one inch Double Diaphragm pump operating at 90 psi air pressure. We applied 10,000 sq. ft. per hour at the rate of two gallons per 100 sq. ft. This same formula utilizing 20 mesh rubber crumb and a different spray process can

apply E-Flex 2 directly to vertical concrete block foundations and above grade walls. Two coats will seal walls to withstand a 4'0" column of water with only a pin hole leakage. This material can be used as a base material for a decorative coating serving as a permanent base that will not crack or peel.

TREATING PLYWOOD ROOF SHEATHING: Our product can be used for treating plywood roof sheathing for waterproofing and anti-skid surface with 20 mesh rubber crumb. In the construction industry, millions of sq. ft. of slippery plywood are applied daily to houseroofs of new homes. By coating one side of this plywood with a latex emulsion with 20 mesh rubber, a new industry could be developed creating thousands of new jobs. Some of benefits of this product are as follows: Elimination of tar paper that usually blows off or tears under workman's feet thereby, causing roofs to leak and workman compensation rates to soar due to accidents caused by their slipping. Roofers and carpenters have been seriously injured and even killed due to the failure of tarpaper applications. Waterproofing anti-skid plywood products can be mass produced on a conveyor dryer indoor system. The product will cure at ambient temperatures. Builders will use it because it can be installed safely without additional cost. All joints can be taped shut just like drywall taping. The result is a waterproof roof with a vapor barrier and an anti-skid surface.

GUNITE SPRAY SYSTEMS: These machines air convey 1/4" rubber crumb in a 1-1/2" hose, 30' long. A second 1" hose carries the latex fluid to the gun. These products are mixed in the gun and sprayed onto the surface. These applications are usually applied to running tracks in 1/8" layers for sun curing. Multiple layers are applied to reached desired thickness. Elastomeric Technologies is currently developing a latex binder to be used with this-system, for a major marketing firm installing athletic running tracks.

WHAT'S IN THE FUTURE: Hundreds of thousands of flat roof buildings are in place today with more under construction. All these roofs have a planned obsolesce of 10 years before failure starts occurring. Billions of dollars are spent annually repairing these roofs. If the architects and designers can build a structure which can last 100 years and beyond, why can't they design a roof to last the life of the building. The reason is professional liability insurance. Hot asphalt multi-ply system has been used for generations. It is accepted as a roof system with no liability to the designers. To make matters worse, they cover the entire roof with crushed stone at the rate of 5lb. per sq. ft. Now you have a nonmaintainable roof.

The crush stone is how they get a UL class A rating. The stone is used for fire and ultra violet protection, however, the sun penetrates the stone and deterioration starts. Other high tech roofing products and membranes are very susceptible to damage. So much so that they require walking pads for tradesmen to service air condition units. Who then pays the bills for these short life cycle roofs? The answer: We the taxpayers as usual.

Our answer is if you can pour a concrete floor, why can't we pour a rubber roof. The answer is <u>WE CAN</u>. Recycled rubber is the answer. An Elastomeric poured roof with latex binders 1/2" thick will expand and contract with the weather extremes. Chlorinated latex's are very flame retardant. The latex formula used in this product has a 25 year track record. By using a fireproof white reflexive topping 1/8" thick, you can get a Class A rating. This roof is fully adhered, no mechanical fasteners needed, it will pass all wind lift requirements. No walking pads are required. These roofs can then be used for outdoor patios, tennis courts and intercity playgrounds. New York City has already adopted this practice.

The challenge is now to make this a reality. The technology is here. Major suppliers of latex will provide chemical engineering skills. Research and development funding will be required for certification. Once developed, Government agencies will have to unlock the barriers and work with developers and not against them, which has been the practice in the past. The architects and designers will have to be educated and engineering data provided for them to understand the composite structures of such a roof. Major university research centers with the proper guidance could complete this project in one year. The Government Agencies and purchasing agents have always accepted the practice that if it isn't a Goodyear or Dupont or similar product, it just simply won't be considered. Elastomeric Technologies Inc., has now been given the green light by Dupont to proceed with final development of this latex formula for recycled rubber uses. Dupont is at the point that they recognize the successful use of neoprene latex in our roofing products. They are now negotiating with us on how they can be useful in helping us promote these products.

As you can see time testing and credibility are the secrets of the successful use for recycled rubber.

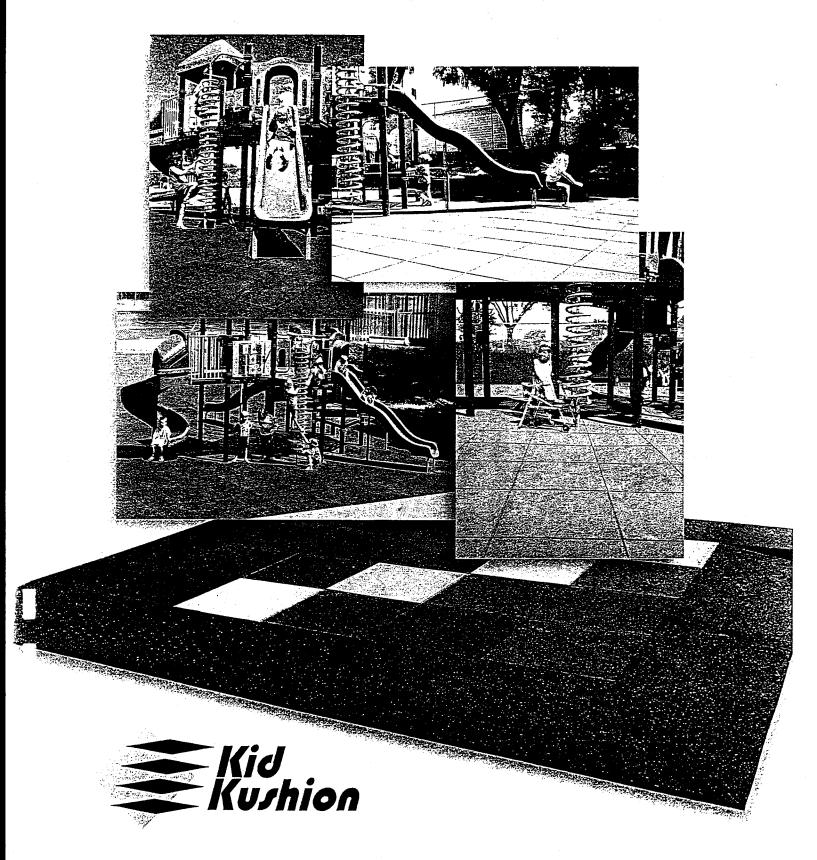
Elastomeric Technologies Inc., solicit your interest in any of these products. Why re-invent the wheel when the answer is already here. License for manufacturing and marketing are available for any of these products. Let us work together and make it happen!

PRESENTATION MATERIALS Crumb Rubber Products

RICHARD POSIMIATA

Environmental Molding Concepts

SAFER PLAYGROUNDS WHILE PROTECTING THE ENVIRONMENT...







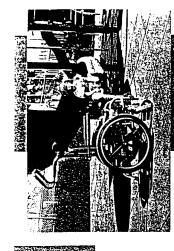




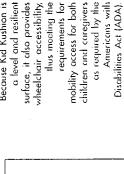




blue, green and black. (Not all colors are shown) colored combinations, including: red, gray, Kid Kushion is available in solid and multi-



Because Kid Kushion is a fevel and resilient wheelchair accessibility, thus meeting the requirements for mobility access for both children and caregivers surface, it also provides





Kid Kushion is the perfect marriage between your playground surfacing needs and

the environment; meeting the safety standards recommended by the CPSC, while

providing a new and innovative solution to the used tire disposal problem.

Standard for Impact Attenuation Under and Around Playground Equipment (ASTM F Molding Concepts, meets the U.S. Consumer Products Safety Commissions (CPSC)

1292-93) for drop heights up to nine feet (9').

Kid Kushion is the safe surfacing solution that is manufactured using crumb rubber

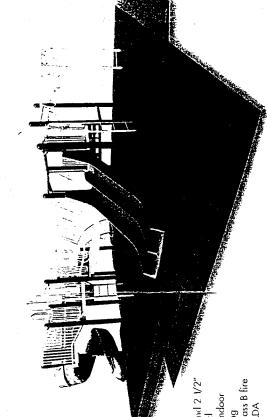
that is 100% derived from the recycling of whole used tires.

Kid Kushion is the environmentally sound solution to providing a safe and resilient

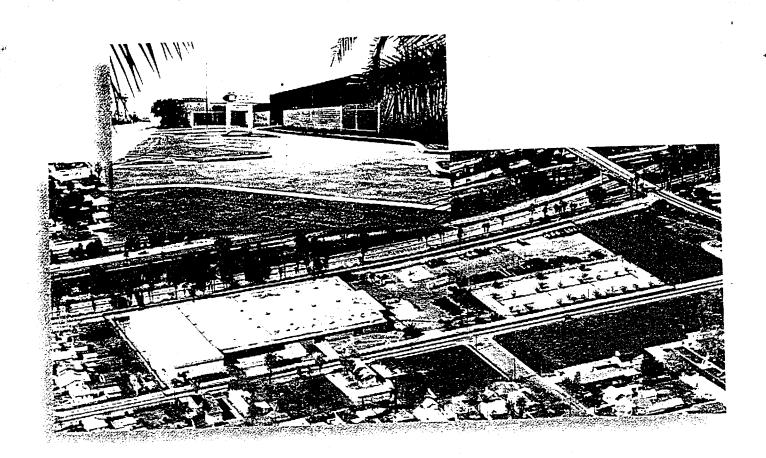
The Ideal Environmental Solution

to Playground Safety

surface in all playground applications. Kid Kushion, produced by Environmental



drainage during inclement weather and can be produced with a UL Class A or Class B fire Kid Kushion is a two foot by two foot (2' x 2') mat surfacing available in 3 1/2" and 2 1/2" applications, the 2 1/2" Kid Kushion is primarily used in meeting the criteria for indoor rating, if required. Kid Kushion also provides transition pieces that meet current ADA installations. Both mats are designed to provide impact attenuation while providing thicknesses. While the 3 1/2" Kid Kushion is suitable for most outdoor playground mobility access standards.



Warranty: Environmental Molding Concepts (EMC) warrants Kid Kushion to be free from manufacturing defects for (3) years.

Contact your local Kid Kushion Agent for additional details.



PRESENTATION MATERIALS Crumb Rubber Products

PAULSCHUBRING

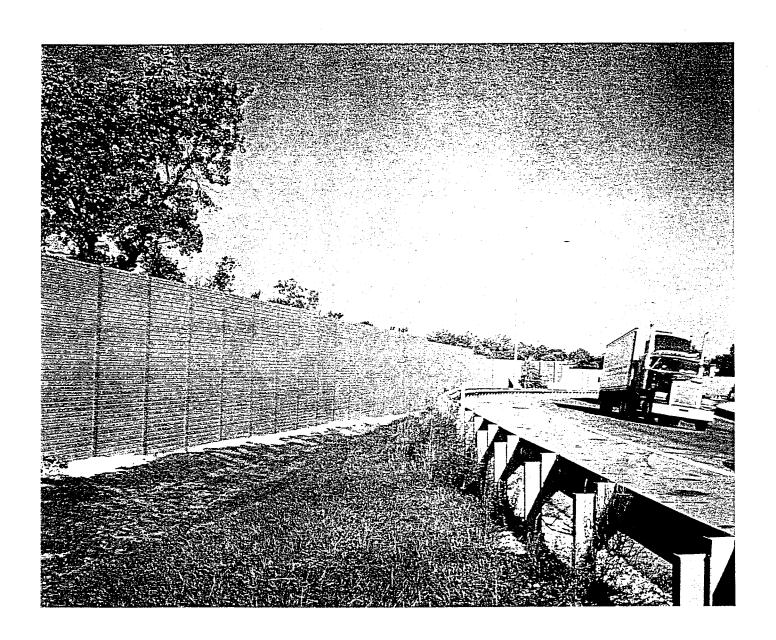
Carsonite International

PRESENTATION MATERIALS Crumb Rubber Products

PAULSCHUBRING

Carsonite International

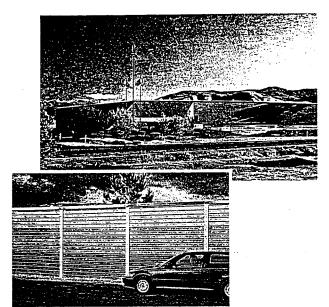
Carsonite® Sound Barrier System



A Sound Solution™

The Carsonite® Sound Barrier System (SBS) meets and exceeds the guidelines set for noise reduction coefficient and wind loads required by AASHTO and State Departments of Transportation for sound barrier walls.

A New Concept in "Quiet" Noise



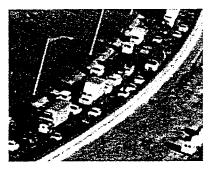
Carsonite International is one of the leading manufacturer's of highway safety products and for almost two decades has been a primary producer of highway safety accessories. A special area of emphasis at Carsonite® has been the development of products that contain post-consumer scrap materials. As a result, Carsonite has created a Sound Barrier which incorporates a substantial amount of post-consumer recycled rubber. The Sound Barrier is attractive, durable and an effective solution to blocking noise. It can be used along highways, crowded residential areas, and mass transit lines which will prevent excess noise from entering into adjoining residential and commercial areas.

Carsonite takes pride in the development of the Sound Barrier. The wall not only addresses the environmental pollution problem of what to do with our nation's discarded tires, it also solves the critical problem of noise pollution found along the highway.

Problems

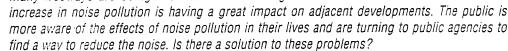
Environmental Pollution

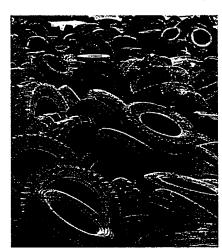
RECYCLE, RECYCLE... the buzz word of the 90's. Many of us are familiar with the recycling of aluminum, steel, glass and paper. What about recycling rubber? The United States creates 250 million used tires annually that could be recycled. The tires are currently being left in massive stockpiles or landfills, creating a nationwide over-supply and disposal problem.



Noise Pollution

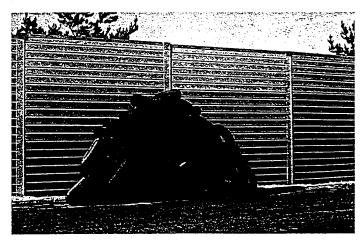
A large number of urban freeways have been built over the past 30 years. Traffic is increasing and many freeways are being widened. The resulting





A Solution

No other product on the market today solves both the nationwide problem of discarded tires and the noise pollution created by vehicular traffic. The Carsonite Sound Barrier utilizes the used tire rubber from the very vehicles causing the noise pollution, to solve the noise pollution problem. The Sound Barrier places recycled tire rubber, the key ingredient in the wall, within a safe, durable composite building member. A ten-foot high wall can consume up to 250,000 pounds of scrap tires (the equivalent of 20,800 tires) per mile of barrier. The Carsonite Sound Barrier is a perfect solution to the environmental and noise pollution problems of today... and tomorrow.



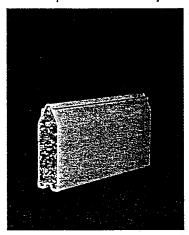
How we do it.

The Carsonite® Sound Barrier is constructed from structural planks made by combining a ground, recycled rubber core within a fiber-reinforced composite channel. The structural channels are made by using a fiberglass pultrusion process. Glass reinforcements are combined with thermosetting resins. flame retardants. U.V. stabilizers and other performance enhancers to form a permanent, rigid closed structural plank.

The core, or recycled tire rubber and polyolefin portion, is mixed with flame retardant additives and shredded recycled plastic scrap, creating the sound attenuating surface which is required in all barrier walls.

Once the composite structural channels have been produced, the rubber core mixture is incorporated into the structural channel. The resulting rubber-filled structural planks are trimmed and assembled into prefabricated panels. which form the CARSONITE SOUND BARRIER.

Composite Assembly



The Carsonite® composite material utilized in the Sound Barrier shell has been used worldwide for decades in demanding, outdoor applications. The glass-reinforced thermoset polymer construction resists fading, cracking, and deformation.

- Barrier Plank Assembly COMPOSITE CHANNEL RECYCLED - RUBBER COMPOUND 6.375
 - Can utilize up to 250,000 lbs. per mile of recycled post-consumer rubber
 - Tongue and groove building planks
 - Versatile applications
 - Variety of designs and colors

PHYSICAL PROPERTIES OF CARSONITE COMPOSITE*

		ASTNI
Flex Strength	60.000 psi.	ס 790
Tensile Strength	60.300 psi.	D 638
Compressive Strength	60.000 psi.	D 695
Tensile Modulus	1,800,900 ps:.	D 638
Specific Gravity	1.3 (typ)	

These properties are valid over a temperature range of -40° to +140°= Physical test reports available upon request.

- Structural integrity
- Load-carrying ability
- Lightweight (7.5 lbs. per square foot)
- Easy installation

Noise Abatement

Carsonite Sound Barrier wall panels, consisting of recycled tire crumb and a composite structural shell, have sufficient density to provide the noise reduction required for an effective barrier.

NOISE BLOCKAGE

S.T.C. Required. 25 minimum Carsonite S.T.C.*....36

S.T.C. = Sound Transmission Class, A measure of sound blockage

* As tested by Riverbank Acoustical Lab, Geneva, III.

The Carsonite Sound Barrier Wall has a noise reduction coefficient (N.R.C.) of 0.15. A higher (N.R.C.) can be attained by using other fascia treatments. Contact a Carsonite Representative for additional information.

Specifications

Width:

Widths available up to 15 feet.

Heiaht:

Nominal height of 6-inch increments. Tallest height available in a single panel is 7 feet.

Thickness:

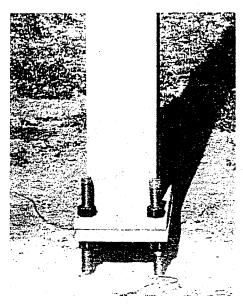
Assembled panel shall have maximum nominal overall thickness of 2-1/2".

Weight:

Average weight 7.5 pounds per square foot.

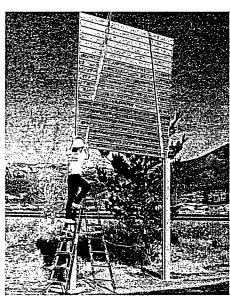
Colors:

Customized colors and a wide variety of fascias are available upon request.

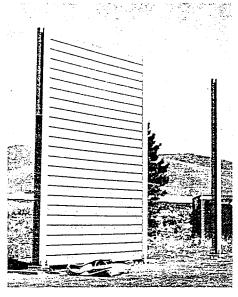


Installation of the Carsonite[®] Sound Barrier is easy. Once supports are firmly in place, the wall panels are ready to be installed.

Installation



The Sound Barrier wall panels are preassembled off site. After the supports are installed, the panels make installation quick and easy. A typical load is 40 panels (or 400 feet) per flat bed truck.



The completed Carsonite Sound Barrier is attractive, durable, long lasting, and meets all the engineering and architectural requirements for an effective Sound Barrier.

Summary

- * Utilizes recycled rubber
- * Extremely long life cycle
- * Ease of fabrication and installation
- * Aesthetically pleasing

- * Color flexibility
- * Architectural fascia versatility
- * Maintenance free
- * Solves environmental and noise pollution problems



10 Bob Gifford Blvd Early Branch, SC 29916-0098 (803) 943-9115 • Fax: (803) 943-3375

(800) 648-7916

Representative/Distributor

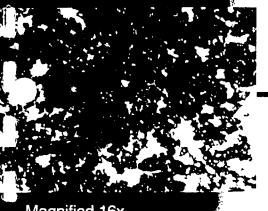
Raul Schubring

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U.S. PATENT NO'S: 5,217,771 5,272,284

PRESENTATION MATERIALS Rubberized Asphalt Concrete

BAS Recycling, Inc.



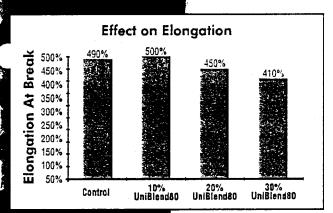
Magnified 16x

UniBlend 80

UniBlend 80 is a low cost dynamic filler that can be incorporated in compounds at the 10% to 30% level without deleterious effects to compound, process, or product performance.

Effect on Tensile Strength PSI 3500 3000 2500 2000 1500 1000 500 20% UniBlend80 30% UniBlend80 Control

UniBlend 80 is a consistent and reliable (P80 Mesh) material derived from the recycling of used tires. UniBlend 80 in your compound will reduce overall compound cost without sacrificing quality or performance. UniBlend 80 undergoes continuous quality inspection and our Technical Staff would be pleased to recommend an optimum loading percentage based on your specific compound requirements.



Physical Properties

- 100% Passing 80 Mesh
- Average particle size = 150 Microns
- Surface area = $0.48 \text{ m}^2/\text{g}$ ASTM method D-4780 using Krypton
- Specific gravity 1.1 to 1.2

Effect on Cure Time MIN 30 25 Cure Time 20 15 10 10% UniBlend80 20% UniBlend80 Control

Chemical Analysis

ASTM D297

% Extractacles 4-16

% ASH 2-10

% RHC 45-65

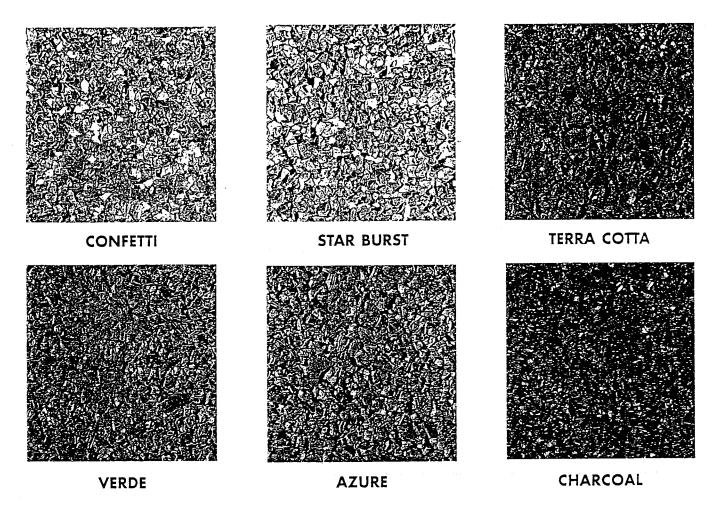
25-35 % CB

Rubber properties using niBlend 80 in ASTM andard Formulation 3192-NR



1400 North "H" Street, San Bernardino, CA 92405 Tel. (909) 383-7050 • Fax. (909) 383-7055

Kushion Color & Specifications Sheet



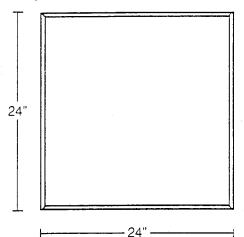
Kid Kushion is available in the standard colors shown and custom colors may be special ordered. The Confetti and Starburst Kid Kushion are from our TuffKid line produced using crumb rubber derived from tire recycling, the top color portion is a custom EPDM. Kid Kushion in our EnviroKid line is produced from 100% recycled tire rubber, including the color portion, and available in TerraCotta, Verde, Azure, and Charcoal. Contact your local Kid Kushion Distributor for assistance in design, layout and color selection for your particular installation.

EMC warrants the full line of Kid Kushion products to be free from Manufacturing Defects.

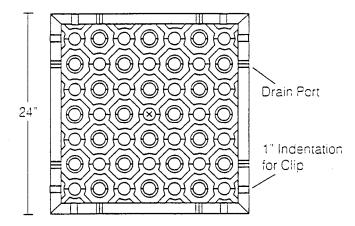


Kid Kushion Tiles & Ramps (Patent Pending)

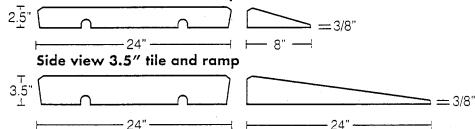
Top view 2.5 and 3.5 tiles

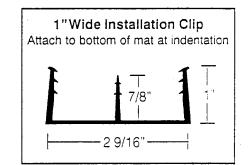


Bottom view 2.5 and 3.5 tiles

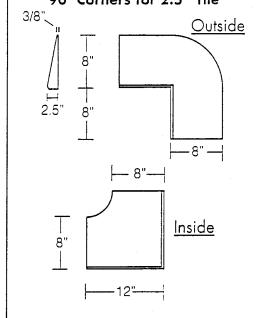


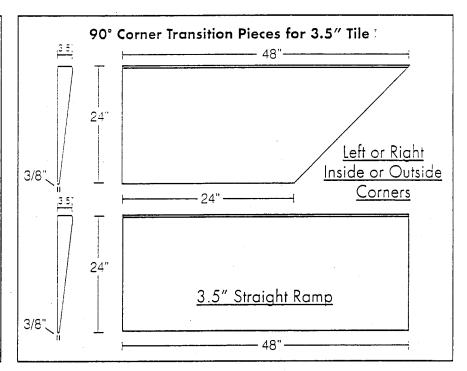
Side view 2.5" tile and ramp



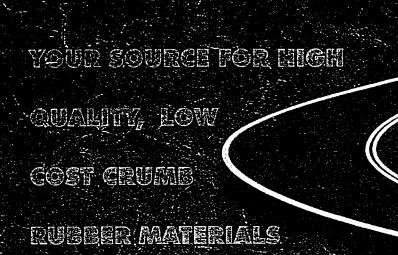


90° Corners for 2.5" Tile



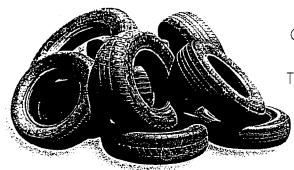








TECHNOLOGICALLY ADVANCED MATERIALS



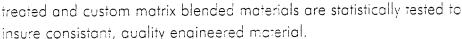
The Leader in Tire Recycling

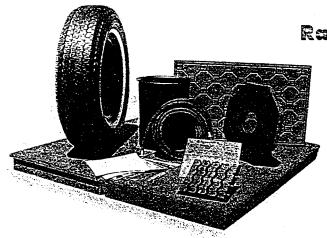
Our recycling technology begins with the separation of used tires into their constituent parts of steel, fabric and rubber. The tire rubber pieces are then processed into crumb rubber.

BAS Recycling, Inc. offer a complete solution to the used tire solid waste problem with the collection and recycling of tires generated by tire dealers, tire manufactures, tire retreaders, and many public agencies.

High Quality Crumb Rubber

The crumb rubber produced is continually inspected to insure quality and is available in a wide range of gradations that is uniform, consistent, and contaminate free. Surface





Raw Material For All rubber Products

The crumb rubber material is produced to gradations suitable for incorporation into rubber mixes using conventional rubber mixing equipment. The resultant mixtures can be moided or extruded depending on application. Our technical staff is available to work with your requirements to develop a custom blend of crumb rubber engineered to specific requirements and available in both a surface treated or untreated material.

Low Cost Engineered Materials = increased Profits

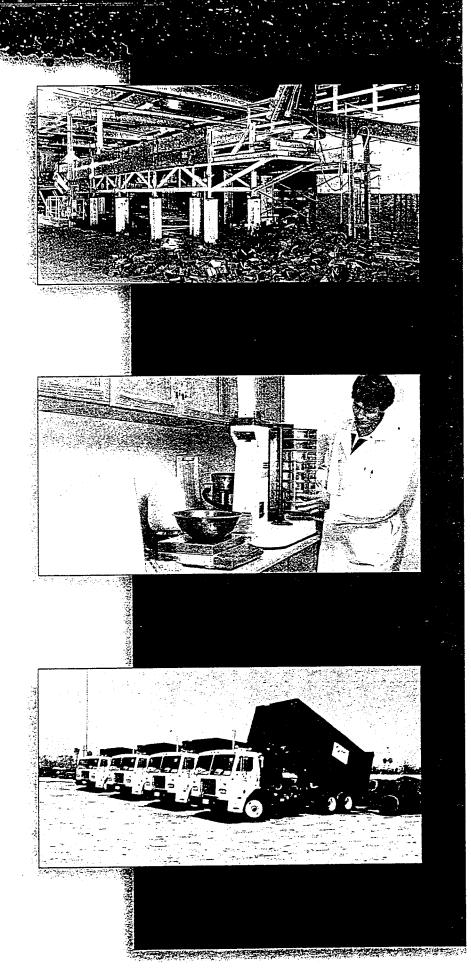
Why is crumb rubber from whole tire recycling suitable for inclusion in your process or product line? The answer is very simple. Reduced Production Cost; using our low cost engineered materials results in increased manufacturing profits. A lower cost alternative to virgin materials, with their skyrocketing prices, allow a price competitive advantage in both new product development and existing product lines.

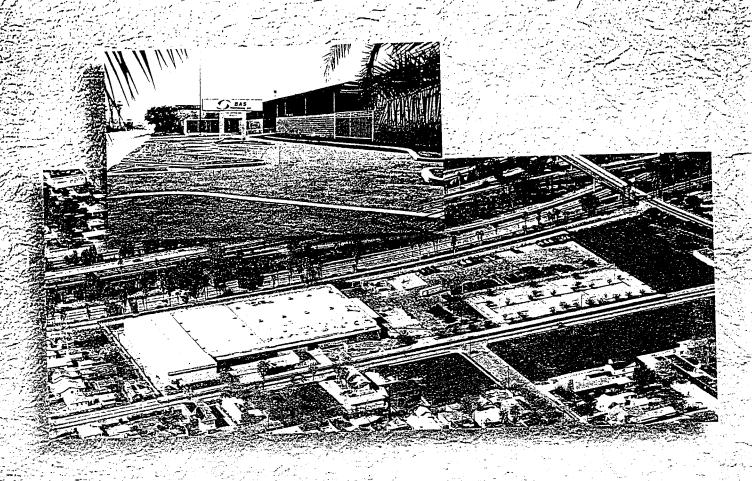


NDUSTRY LEADER & INNOVATOR

Tomorrow's Technology, Available Today...

BAS Recycling, Inc.'s entry into the whole tire recycling industry dates back to the opening of our original facility in 1989. Those early efforts led us to an understanding of the challenges involved in the production of quality, contaminate free, crumb rubber from whole tire recycling. Continuing as the industry leader and innovator, BAS Recycling, Inc. is the first tire recycling company to offer custom matrix blending of recycled materials and technical support to optimize incorporation of our treated or untreated materials.





BAS Recycling, Inc's 80,000 square foot facility, on seven acres, has the production capability to fill even your largest crumb rubber demand. We can supply from our multi-million pound Storage Area with same day order and shipping.



1400 North "H" Street, San Bernardino, CA-92405 — Tel. (909) 383-7050 • Fax. (909) 383-7055

PRESENTATION MATERIAL Rubberized Asphalt Concrete

TOMKIRK
Willdan/Associates

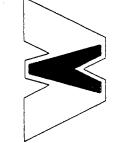
ASPHALT-RUBBER REACTION

New Definition: Dissolving rubber in asphalt to attain homogeneous molecular bonding between asphalt and rubber molecules.

Topics:

What are the ramifications of under-reaction? What is the nature of this reaction? What constitutes a full reaction? How is a full reaction detected?

Speaker: Tom Kirk, Registered Civil Engineer Willdan Associates



PRESENTATION MATERIALS Crumb Rubber Products

PETER SPENDLOVE

Sports Advancement and Research Co., Ltd.,



Sureflex Technology

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1	Introduction and bibliography of project team leaders
2-5	Impact absorbing asphalt - details of the Technology
6	Performance specifications - Sureflex Hockeystar
7	Performance specifications - Sureflex Playstar & survey of playground incidents from Redmile Primary School
8	Projected tonnages - 18 countries
9	Sureflex Product list

SUREFLEX TECHNOLOGY

Introduction

Sureflex is an, Elastomeric Impact Absorbing Asphalt. A pioneering Technology, developed by the University of Nottingham in conjunction with SARCO, Tilcon (South) Ltd and Shell Bitumen. A designed material which is applicable to many different industries. Resulting in a range of products, many of which have not yet been conceived.

Sports Advancement & Research Co Ltd

SARCO's purpose is to Licence asphalt manufactures to produce and market the range of products as they are developed in conjunction with the University of Nottingham.

Sureflex is a registered Trade Mark.

The Sureflex Technology is world patent pending

Sureflex was invented by Peter Spendlove MIAT.

Peter Spendlove is Managing Director of Sports Advancement and Research Co Ltd.

Peter, 25 years main stream architecture, entered the sports surfacing industry as Project Manager with Balsam UK in 1990. Responsible for designing and building of 50+ synthetic pitches and 6 athletics tracks. Left Balsam at the request of Fitzpatrick Civil Engineering to start a Sports Surfacing Department for the company. Left Fitzpatrick in May 1995 to develop the Sureflex Technology in conjunction with Dr John Read of Nottingham University and Shell Bitumen. Enablers to bring the Technology to the market place included, Tarmac Industries and Leigh Environmental

Sureflex Technology Dr John Read BEng (Hons), MIAT, MIHT

John Read, PhD, now Technical Manager of Croda Bitumen, joined Nottingham University as Research Officer in 1995 with special responsibilities for research into the behaviour of bituminous materials. His first degree was in materials engineering and he has recently been awarded his PhD on fatigue cracking of bituminous paving mixtures. His experience before academia concerned running asphalt and concrete plants and dealing with all technical matter relating to civil engineering materials for a major civil engineering contractor. During this time he also gained considerable practical quarrying experience. He is presently involved in a joint project between Nottingham and Cambridge Universities on bituminous materials. Among other things he brings expert knowledge of materials and considerable computing skills to the team.

Sureflex Technology Dr Andrew Collop

Andrew Collop PhD, joined Nottingham University as a Lecturer in 1995. After he completed his PhD at Cambridge University he continued to work on the interaction between heavy goods vehicles, the environment and pavement materials. His general interests are in the area of dynamic vehicle pavement interaction and the mechanical behaviour of bituminous materials. Among other things he brings expert knowledge of mechanics and dynamics and considerable computing skills to the team.

Impact Absorbing Asphalt

Authors Peter Spendlove & John Read PhD B Eng (Hons) MIAT MIHT

Present Technology

The concept of using recycled tyres as an additive to flexible pavements is generally accepted as having been conceived in the States in the 1960's and highways agencies have been evaluating rubber crumb modified technology in hot mix asphalt since that date. Numerous technologies have been studied with varying degrees of success. The most significant of these is the wet process, which consists of the modification of the bitumen by the incorporation of less than 600 µm diameter powdered rubber, the result being a binder in which the elastic phase remains dominant at high temperatures (up to 50°C) giving the road surface a high resistance to permanent deformation and a lower temperature susceptibility. The arrival of block copolymers, such as Styrene-Butadiene-Styrene (SBS), has now generally replaced this process due to their enhanced performance (increased resistance to permanent deformation, fatigue cracking and thermal cracking), and better storage stability over long periods, due to better chemical compatibility. There are also no concerns over the durability of SBS binders, which cannot be said for crumb rubber modified ones. These methods of modifying the performance of binders for road construction are well developed and documented, however, little or no work has been carried out into the IMPACT ABSORBING characteristics that occur if the quantity and particle size of rubber is increased to such as point as to become a volumetrically major proportion of the mixture.

Current thinking for impact absorbing surfaces concentrates on the use of resin, or polyurethane, as the binder with a large size of rubber crumb, typically 2mm to 5mm in diameter, used to impart the Impact Absorbing properties. This technology, generally relates to BS 7044 and BS 7188, and concentrates on the Sports Surfacing and Children's Safety Surfacing Industries for its applications.

SARCO (Sports Advancement & Research Co Ltd) conceived the idea of combining the two technologies, and following subsequent research, with the Department of Civil Engineering at the University of Nottingham, Sureflex was born and patented worldwide.

Sureflex Technology

The Sureflex Technology research has produced a range of remarkable new materials. The first three in commercial production are, Sureflex Playstar, Sureflex Hockeystar and Sureflex Tennistar which comply with BS7188 and BS 7044. The essence of the technology is in achieving a continuous elastic phase throughout the full depth of the material, providing an instantaneous deformation and return mechanism. There is also a viscous phase in the material that allows damping (energy absorption), and a plastic phase to accommodate plastic strain without cracking. The polymer-modified bitumen used in the materials plays a key role in joining the discrete particles of crumb rubber to form the elastic phase. The natural visco-

elastic nature of the bitumen supplies the viscous, or time-dependant, phase and the aggregate "skeleton" provides plasticity. Performance of the Impact Absorbing Asphalt can be adjusted to suit any application by altering the ratios of the elastic, viscous and plastic phases. In practice, this is achieved by altering the volume fractions of the bitumen, rubber, and aggregate, and the particle size distributions of the rubber and aggregates. For example, to make materials suitable for a sprinting track the elastic phase can be increased to dominate the properties, whereas a long distance running track needs a more viscous response. Other applications may be designed for by changing the source of crumb rubber (which changes the response). Softer rubber (from earth-moving tyres for example) produce asphalts more suitable for safety surfaces as they provide a higher degree of "shock absorption". Conversely using harder rubbers produces harder wearing surfaces more suitable for pedestrian usage. The Technology uses existing asphalt production equipment and therefore requires no additional capital expenditure by the manufacturer. The aggregates and binder are heated and added to the pugmill to which the rubber is added cold (to reduce softening). The temperature of the final mixture when it comes out of the pugmill is around 145°C, allowing it to be laid with conventional asphalt-laying equipment. Once mixed, the material is placed in a well insulated lorry where it can remain for up to four hours with little or no loss in temperature. This allows a single production facility to produce material for laying within a 200 mile radius. Material is laid conventionally by pavior or by hand, following tight quality control procedures. The consortium (University of Nottingham, SARCO and Tilcon) has written production, laying and performance specifications. ensuring that the product proves durable and cost-effective in service. The finished surface, in the case of Sureflex Playstar, is ready to be used within a few hours, once the temperature of the material has cooled to the ambient air temperature. Sureflex Hockeystar on the other hand is ready to take the grass carpet for all weather sports pitches as soon as the laying process is complete.

Environmental Impact

The new Technology produces a range of simple, cost effective and environmentally friendly products. It has the potential to make use of a significant proportion of the UK scrap tyre stream, currently running at 350,000 tonnes per year. At present tyres are considered a hazardous product and are generally land filled or incinerated. New environmental tipping charges in the UK are resulting in fly tipping causing additional health and environmental problems and currently less than 10% are recycled, most of which is into the Sports Surfacing Industry. The concept of treating tyres as a resource and not a waste is not inconceivable and may place a value on the tyres in the future, but before that can happen the vast stock piles across the world have to be utilised. Sureflex replaces aggregates with rubber crumb, thereby reducing the environmental impact of quarrying virgin aggregate. With a health bill of £½bn being spent on repetitive strain injuries on sports fields and probably 10 times that on injuries incurred by falls on asphalt pavements and playgrounds. The cost effectiveness of Sureflex makes it a very attractive technology to Local Authorities, that now have to answer to both the environmental, health and safety lobbies. France is already a step in front of the UK, with a new

law passed in December 1996, requiring Impact Absorbing Material to be laid on all childrens play areas. The proposed targets in the UK for the year 2000 are 10% prevention, 25% retreading and 65% recovery. Current estimates of waste tyre use are that $\pm 5\%$ are absorbed in civil engineering, environmental/safety applications, etc., with at least that amount used in crumbing/granulating. Each country is taking a different approach to the problem, and in some instances, exporting to neighbours on a legitimate commercial basis which only exasperates the global problem. The principle reason for this world merry go round is the lack of use for the end products. The Sureflex technology answers these questions, being cost effective, environmentally friendly and of benefit to the community.

Research & Development

A three year programme of research and development work is currently underway at the University of Nottingham. This work involves detailed chemical and physical study of the range of materials being produced, the development of dynamic test equipment, consideration of the thermal and sound conductivity properties, the use of alternative sources of raw materials and further modification techniques to optimise the bitumen. Commercial products will continue to be developed, predominantly into the field of civil engineering: as a Stress Absorbing Membrane Interlayer (SAMI) in roads where thermal or ground movement has resulted in cracking of the wearing course; as an alternative to concrete floor screeds, and many other uses, some possibly not yet conceived. The project team considers that in excess of 20 products may well be developed out of the generic technology. With applications into all industries.

Some of the most interesting work will be carried out in conjunction with Nottingham Queens Medical Centre. The need for research into possible relationships between the use of artificial surfaces and injury incidence has recently been highlighted. The common assumption has been that the use of materials with increased shock absorption characteristics will result in a lower probability of impact injuries. Biochemical measurements of ground reaction forces and lower body limb kinematics have been used in the literature to provide indications of the loading experienced by the structures of the lower body. It has been found that using a material with enhanced mechanical shock absorbing properties as part of the sports surface does not necessarily reduce the maximum loading experienced by the human body during sporting activity. It is, therefore, apparent that in addition to quantifying and optimising the mechanical properties of surface materials, a study of the complex interaction between the human body, the shoe and the sports surface is required. The proposed research therefore includes an investigation of the influence on bio-mechanical variables of impact with surfaces with differing mechanical properties.

Benefits of the New Technology

Public heath and fitness will benefit directly from the technology due to the provision of sports surfaces optimised to meet the performance and safety requirements of selected sports activities. The reduced cost of the material, relative to traditionally used materials, will increase the ability of local councils and private companies to fund the laying of sports surfaces. For the average user, the likelihood of injury occurrence will be reduced thus, decreasing medical costs. In addition, the reduced injury occurrence will allow continued activity and, thus, increased cardiovascular fitness and reduced medical costs from cardiovascular disease will result. For elite sports people the reduced injury incidence resulting from the use of optimised surfaces will allow increased training at an appropriate level and thus improved performance. The use of the material in children's playgrounds will reduce the incidence of injury to children. The UK public will also benefit from the reduction in the environmental impact of waste tyres. Public funding regarding the storage of waste tyres will be reduced. The UK construction market will benefit from new product availability into a currently depressed market and the UK

balance of payments will benefit from the sale of UK Technology overseas.

Concluding Comments

Sureflex is currently sold under licence by Tilcon (South) Ltd, and can be obtained directly from any of the Tilcon batching plants. The present product range consists of, Sureflex Hockeystar, an open textured material. Designed to comply with BS7044 and various governing body requirements. This product replaces both the traditional asphalt base and shockpad, normally associated with engineered designed synthetic pitches; showing a 25% saving on the capital cost of a new pitch. Sureflex Playstar and Sureflex Tennistar are designed as a dense wearing course or single layer material, replacing traditional 6mm dense or open textured asphalt. The products are intended for school, municiple and community playgrounds, footpaths and cycle tracks either for new build or as an overlay to existing asphalt or concrete surfaces, and when coated with an acrylic water based paint, Tennis courts. The cost is comparable to 6mm dense asphalt when the increased spread rate is taken into consideration. Sureflex Safestar is designed to comply with BS7188 for impact severity when installed at the appropriate thickness below play equipment.

- 1 Anon "Artificial sports surfaces." BS7044,BSI,1990
- 2 Anon "Play equipment intended for permanent outdoors." BS5696.BSI,1986
- 3 Nicholl, J.P. "Injuries in sport and exercise main report." The Sports Council, 1993
- 4 James Marsh DTI
- 5 Goodbody, J. "Is this the penalty we must pay for a perfect pitch" The Times, London, Nov. 4th, 1996

Performance Specification - SUREFLEX Hockeystar

Introduction

The Sureflex Technology is Patent Pending No.PCT/GB96/01240 and is an Impact Absorbing Elastomeric Asphalt. Sureflex Hockeystar is designed to replace the traditional combination of asphalt base and insitu or pre-fabricated rubber resin shockpads, situated below sand filled or non-sand filled synthetic carpets, associated with synthetic hockey pitches and multi-sport pitches.

Performance

Sureflex Hockeystar (40mm thick) when tested by Materials Science Consultants using a typical 24mm synthetic carpet and a silica sand compacted to within 2mm of the top of the carpet, complies with impact, ball bounce and porosity tests required by the following Governing bodies:-

Current F.I.H. requirements @

- i. BS 7044 for impact absorbing surfaces **
- ii. English Hockey Associates #
- iii. Football League (Winterbottom Enquiry) *

Typical set of Performance Tests:-

PROPERTY	ζ.	UNITS	ACCURACY (±)	RESULTS	SPECIFICATION VALUES
Hockey Ball (from 1.5m) Soccer Ball I			(10)	120	100-350#
(from 3.0m)	Cenomin	(%)	(0.5)	41%	32-42*
(110111 3.0111)		(/0)	(0.5)		25 - 50**
Force Reduction		(%)	(1)	50.5	40-70#
		,			50 - 75*
Peak Deceler	ration				
from 1m	Dry	(g)	(10)	142	≤200 * *
	Wet	(g)	(10)	148	≤20 0** #
Peak Deceler	ration				
from 1.5m	Dry	(g)	(10)	196	_ ≤225*
	Wet	(g)	(10)	200	≤225*
Permeability		(Mm/h)		1120	≥150@

Pitch Design and Construction

Sureflex Hockeystar in NOT intended to provide the finished surface. Therefore all edges must be laid up to a concrete or traditional material edge to prevent fretting. Sureflex Hockeystar can be laid to different thicknesses, but is most cost effective when laid through a pavior at 40mm directly onto compacted stone foundations. If there is a requirement to lay Sureflex Hockeystar as a wearing course or less than 30mm. It is incumbent on the contractor to advise the supplier to ensure that the performance requirements can still be achieved. Because Sureflex is elastic, it will accommodate differential movements caused by thermal expansion or contraction. It can therefore be laid over existing hard surfaces, where residual cracking has occurred. Sureflex will follow ground or foundations movements and care should be taken to ensure adequate foundations are constructed prior to laying.

Performance Specifications - SUREFLEX Playstar

Introduction

The Sureflex Technology is Patent Pending No.PCT/GB96/01240 and is an Impact Absorbing Elastomeric Asphalt. Sureflex Playstar is designed as a 25mm thick dense impact absorbing surface for school, municiple play areas and ball sport areas. Where the enhanced performance reduces player fatigue and impact damage through falling, but, still retaining ball bounce commensurate with traditional asphalt surfaces.

Performance

Designed to meet BS7188, where an impact severity index of 1000 from 600mm is required.

Construction

Sureflex Playstar can be laid directly onto a new compacted frost resistant stone base, or on top of existing surfaces at any thickness over 25mm. If the existing surfaces have suffered from residual cracking or are broken up, Sureflex Playstar will fill and cover these areas, and retain its integrity up to a given amount. Being elastic in nature it will follow any further ground or base movement. Care should therefore be taken to ensure a sound base or foundation. Sureflex Playstar is a finished surface and as 95% of the compaction is through the paving machine with rolling giving the final finish. The surface will accept pedestrian traffic immediately it cools to ambient temperature.

Survey of Playground Incidents from Redmile Primary School

On playground incidents - categories have been determined as either grazes or bumps. The severity of either is not shown in the incident reports. It is therefore assumed that the children used their own discretion as to whether or not to report to a teacher.

Periods are October 1995 to February 1996 the play ground surface was dense asphalt.

6mm Dense	Asphalt 1995-1996	Sureflex Pla	Sureflex Playstar 1996-1997				
Week No	Graze Bump Total	Week No		Bump	~-		
44-08	20 29 49	44-08	1.2	14	27		

October 1996 to February 1997 SUREFLEX PLAYSTAR was overlaid on the existing asphalt. Sureflex shows a 40% improvement over the same period on grazes and a 45% improvement on bumps. Comments by the teachers - is that children still fall and most treatment is tender loving care as opposed to medication, to alleviate the shock of falling, rather than the injuries sustained. A reasonable conclusion would be the extent of injuries is reduced even more than the figures suggest.

Projected Tonnages of Sureflex. Bitumen and Rubber

Calculations based on UNESCO Year Book 1995 giving number of first level schools per country.

Assumption:-

Each school playground is 1000m² and replaced every 20 years. Coverage at 25mm at 30m² per tonne. An additional 50% is added to accommodate community play areas.

Note:- For Hockeystar the known tonnage is 216,000 throughout 9 E.C. Countries. No specific split is known. This figure has therefore been approximated to the appropriate Countries. All figures in tonnes.

Country	Hockeystar	Playstar	Total	Bitumen 8%	Rubber 27%	Tyre Lake	% Impact
AUSTRALIA		24000	24000	1920	6480		
BELGIUM	24000	12474	36474	2917	9847	111000	9
DENMARK	24000	7668	31668	2533	8550		
FINLAND		12000	12000	960	3240	,	
FRANCE	24000	124968	148968	11917	40221	3.3m	1.2
GERMANY	24000	116283	140283	11222	37876	300000	12.6
GREECE		22959	22959	1936	6198	1.87m	0.33
IRELAND		9864	9864	789	2663		
ITALY	24000	64134	88134	7050	23796	680000	3.5
MALAYSIA		21000	21000	1680	5670		
NETHER- LANDS	24000	25000	48993	3919	13228	42000	31
NEW ZEALAND		6540	6540	523	1765		Charles speeds
NORWAY		10056	10056	804	2715		
PORTUGAL	24000	37416	61416	4913	16582		
SINGAPORE		609	609	50	164		
SPAIN	24000	49620	73620	5889	19877	67000	29
SWEDEN		12759	12759	1020	3445	65000	5.3
UK	24000	72000	96000	7680	26000	350000	7.4
TOTALS	216 000	629 350	845 350	66 622	228 317	N/A	N/A

Note: Tyre figures courtesy of ETRA

Sureflex Product List - May 1997

Commercially in Production

Hockey Pitches
Children's Playgrounds
Footpaths etc.
Ball Courts
Cycle Tracks
Tennis Courts - Dense and Porus

Under Development

Light Transit Rail Track, bed/insulator
Equine Surfaces
SAMI-Interface material below wearing
courses in roads where movement occurs
between base and wearing course
Railway Sleeper Bases
Sound Insulations Barriers
Athletics Tracks
Stud Resistant Golf Course Footpaths
Safety Surfaces

Suggested Applications

Pipeline Insulation
Safety Barriers
Sea Defences
Bollards
Traffic Calming
Pipeline Foundations
Heavy Machinery Foundations
Aircraft Runways Landing Zones
Prefabricated & Insitu Building
Components
Car Park Decks
Screeds

Designation

Sureflex Hockeystar Sureflex Playstar Sureflex Playstar Sureflex Playstar Sureflex Playstar Sureflex Tennistar

PRESENTATION MATERIALS Rubberized Asphalt Concrete

JOEGOLDHAMMER

San Diego County Materials Testing Lab

THE USE OF CRUMB RUBBER MODIFIED ASPHALT PRODUCTS IN SAN DIEGO COUNTY

Crumb rubber products have been used by the San Diego County Department of Public Works for twenty years.

The first use was a parking lot crack sealing project constructed in August 1977. This material is still in place and performing well.

The excellent performance and apparent lack of aging of this material prompted us to try further use of this material. After observing successes from other public agencies using this product, we began a chip seal program with a test section in the desert in 1987 and moved into overlays with crumb rubber modified binder in 1992.

The chip seal test section in the desert is still in service and performing well even in the severe climate. Some of our overlays that have been down for 4 to 5 years show no reflective cracking. These overlays are 1-inch thick on residential streets and only a maximum of 2-inches thick on major roads and haul roads. We have more wet process than dry (rubber added as aggregate).

The 4 attachments summarize the different maintenance uses we have tried for crumb rubber modified asphalt cement.

Each attachment indicates the following:

- 1. The type of maintenance performed.
- 2. The types of binders (modifying process).
- 3. The types of roads on which the binder was used.
- 4. The year we began.

The last attachment gives a summary of the specifications used for each binder type.

San Diego County plans to continue to use crumb rubber modified binders and encourages other agencies to do the same.

USE OF CRUMB RUBBER MODIFIED ASPHALT PRODUCTS IN SAN DIEGO COUNTY

CRACK SEAL

Type of Binder

Basic McDonald Process

Facilities

Parking Lots and Airports Only

Year Started

1977

OVERLAY

Basic McDonald Process PBA6GR Type of Binders

Plus Ridera Dry Process Generic Dry Process

Thickness

1" to 2" depending on structural needs.

Type of roads

McDonald & 2 Dry Processes McDonald & 2 Dry Processes **McDonald** Farm to Market Rural Collector Residential

Major (4 lane)

McDonald

McDonald and 2 Dry Processes PBA6GR and McDonald 2 Dry Processes Commercial/Industrial Haul Road (4 lane)

Landfill Road

Planning two test sections using Caltrans proposed "MB" Specifications

Year started

III. CHIP SEAL

Type of Binders

Basic McDonald Process Polymer Modified with Crumb Rubber Digested Crumb Rubber (Trial Basis)

Type of Roads

Digested Crumb Rubber used on an Inland Valley Road Desert Roads only using hot precoated chips.

Year Started

Test 1987 - Production 1993

IV. SPECIFICATIONS

McDonald Process

rubber, gap graded aggregate for overlay, 3/8" chip for Chip Caltrans Specification, use extender oil, 18-20% crumb Seal

PBA6GR

11% fine (<80 sieve) crumb rubber, 1% polymer, dense graded mix for overlay (no curing time)

> Polymer Modified Chip Seal

6% Polymer, <2% crumb rubber, 5/16-inch chip, refinery blended.

Trial Chip Seal

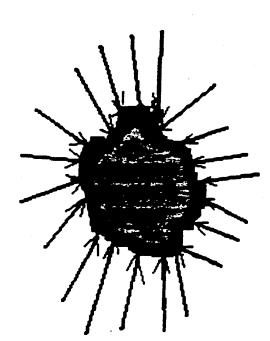
5% ground rubber w/digester (proprietary) 5/16-inch chip refinery blended

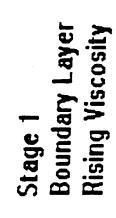
Plus Rider (Dry)

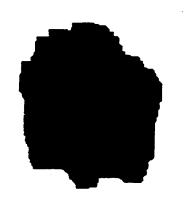
3% total mix weight crumb rubber (proprietary)

Generic Mix (Dry)

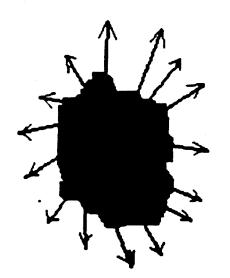
1.2% total mix weight crumb rubber. Dense grade aggregate, AR4000 base asphalt





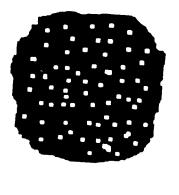


Stage 2 Saturated Particles Peak Viscosity

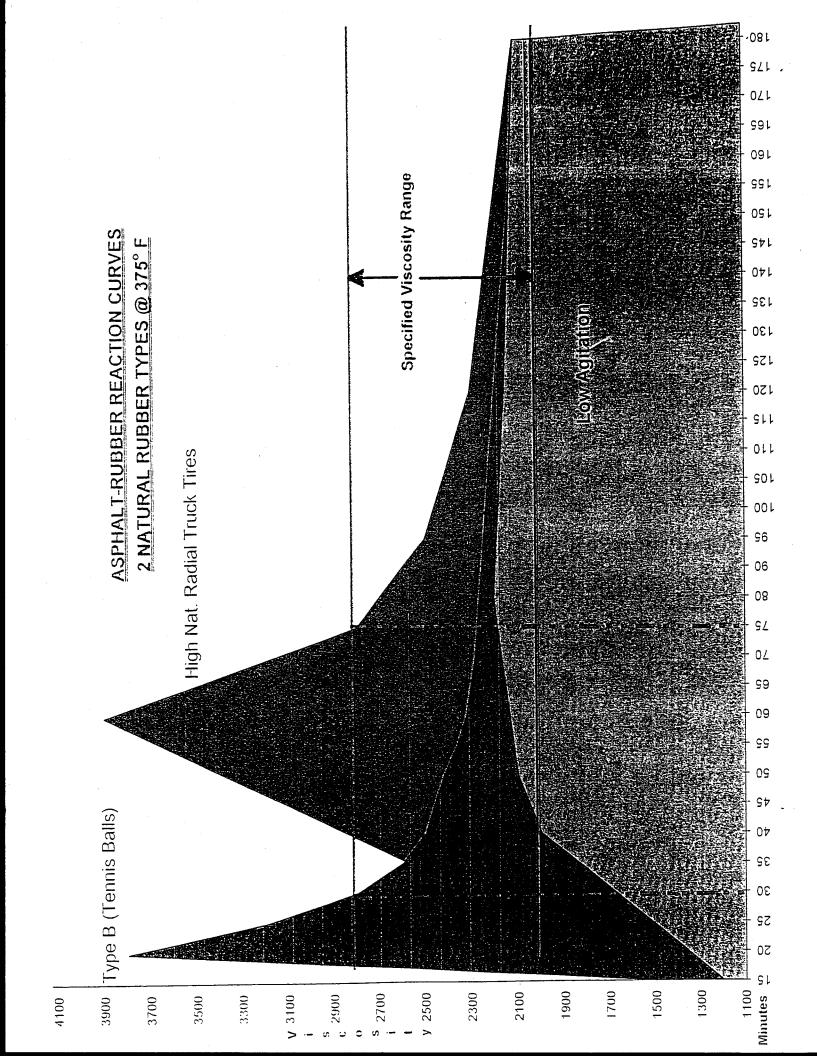


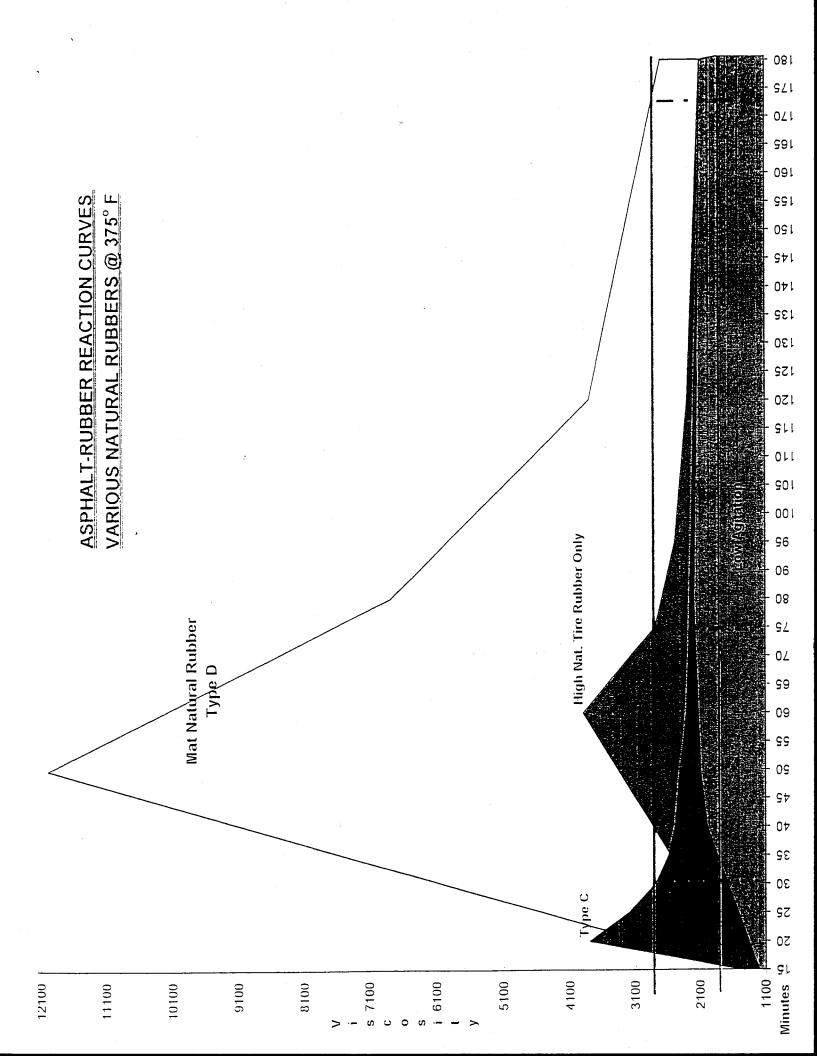
Stage 3 Dissolving Particles Falling Viscosity

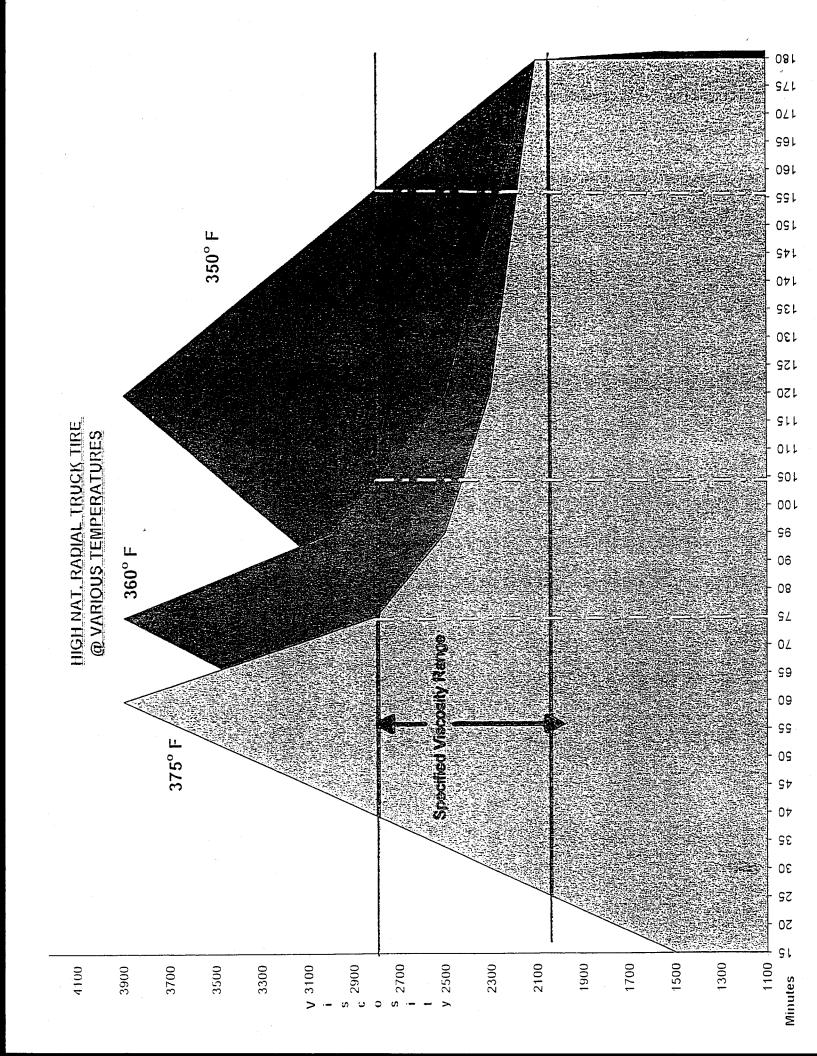




REACTION







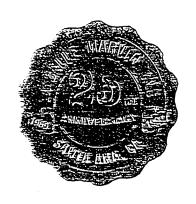
SOILS, ASPHALT TECHNOLOGY

PROFESSIONAL PAVEMENT ENGINEERING

A CALIFORNIA CORPORATION

March 28, 1996

Mr. Al Baca
Baca Associates, Inc.
1141 N. Lemon Street
Anaheim. California 92801-2503

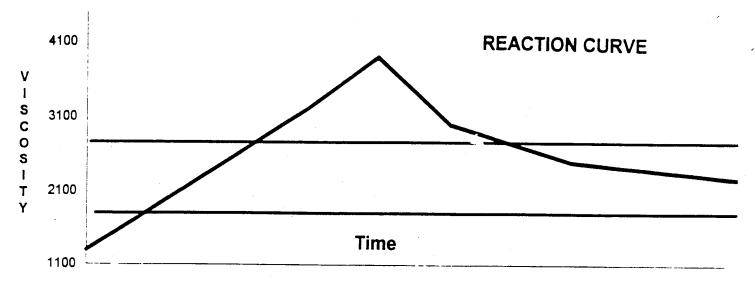


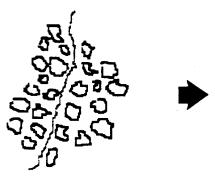
Project No. 23481

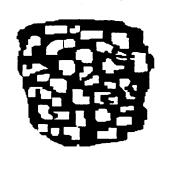
Dear Mr. Baca:

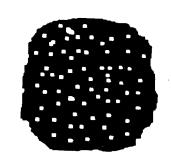
Testing of the rubberized A.C. overlay samples, received in our laboratory and identified as Baca Project No. A-1072-I, has been completed with the following results.

Gradation			The Mark		
<u>Sieve Size</u>	<u>A-1</u>	<u>A-2</u>	<u> </u>	<u>A-4</u>	<u>A-5</u>
3/4" / 19mm	100	100	100	100	100
1/2" / 12.5mm	97	95	96	97	96
3/8" / 9.51mm	83	79	80	3. 80	76
1/4" / 6.35mm	5 6 -	51	50	50	47
#4 / 4.75mm	40	36	35	34	32
#8 / 2.36mm	25	22. 📜	20	- 18	17
#16 / 1.18mm	18	16	15	14	13
#30 / 600um	14	13	11	/ 11	10
#50 / 300um	11	9.6	8.6	8.2	7.7
#100 / 150um	7.4	6.8	选与6.27%	চ _ক ্ 5.9	5.6
#200 / 75um	5.1	4.8	4.4	4.1	4.0
Extraction, % Total E (Agg. Wt. = 100%)	Sinder 8.4%	7.7%	7.6%	8.3%	8.3 <i>%</i>
Extraction, % Rubber (by total Binder Wil)	13.9%	11.9%	11.1%	11.3%	15.1%
Rubber Loss	30%	40%	44%	43%	25%









Wet Process

	Equiva	lent	DRY	Process
--	---------------	------	------------	----------------

325° F

None

50 seconds

-Temperature-

-Agitation-

-Mixing Time-

WET

375° F

High

3600 seconds

Original
Particle Size

Dry Process



Wet Process



Nominal 30 Sieve (.6 mm)

Nominal 16 Sieve (1.18 mm)

COMPARATIVE PROPERTIES OF REACTION STATES

REACTION STATE:

UNREACTED (DRY) BINDER

SEMI-REACTED BINDER

FULLY REACTED BINDER

QUALITIES -

FREE ASPHALT

RESTRICTED BINDER

ASPHALT-RUBBER BINDER

RAMIFICATIONS -

BLEEDING

RAVELING

HIGHLY STABLE BINDER

PERFORMANCE -

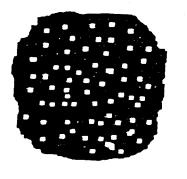
MODIFIED ASPHALT STRENGTH (UNCERTAIN VALUE)

POOR BINDER STRENGTH

2:1 THICKNESS RATIO







REACTION

PRESENTATION MATERIALS Rubberized Asphalt Concrete

FRANKLANGASTIER

Los Angeles County Department of Public Works

"GREENBOOK" STANDARD SPECIFICATIONS FOR PUBLIC WORKS CONSTRUCTION

1997 EDITION

Written And Promulgated By
Joint Cooperative Committee of the
Southern California Chapter
American Public Works Association
And Southern California Districts
Associated General Contractors of California

PUBLISHED BY

ENil. Building News

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Rubber Aggregate - That portion of the crumb rubber modifier added to a hot mix asphalt mixture using the dry process which retains its physical shape and rigidity.

Rubber Modified Hot Mix Asphalt (RUMAC) - A dry process of hot mix asphalt mixtures which incorporate crumb rubber modifier primarily as rubber aggregate.

shredding - The initial process that reduces the whole scrap tires
into pieces.

Asphalt-Rubber and Aggregate Membrane (ARAM {SAM}) - A surface treatment using an asphalt rubber spray application and cover aggregate.

Asphalt-Rubber and Aggregate Membrane Interlayer (ARAMI {SAMI}) - A membrane beneath an overlay designed to resist the stress/strain of reflective cracks and delay the propagation of the crack through the new overlay. The membrane is a spray application of asphalt-rubber binder and cover aggregate.

Wet Process - Any method that blends crumb rubber modifier with the asphalt cement prior to incorporating the binder in the asphalt paving project.

600-2 CRUMB RUBBER MODIFIED (CRM) BINDERS AND PAVEMENTS - WET PROCESS

600-2.1 ASPHALT-RUBBER

- 600-2.1.1 General. Asphalt-rubber shall consist of a mixture of paving asphalt and crumb rubber modifier (CRM) and shall conform to Type A, B, C, or D, or as specified or contained in the Contract documents.
- 600-2.1.2 Type A Asphalt-Rubber shall be a combination of whole scrap tire CRM, paving asphalt and diluent (when required for spray applications) meeting all requirements of Subsection 600-2.
- 600-2.1.3 Type B Asphalt-Rubber shall be a combination of whole scrap tire CRM, natural CRM, paving asphalt and asphalt modifier meeting all requirements of Subsection 600-2.
- 600-2.1.4 Types C Asphalt-Rubber shall conform to all of the requirements for Type A Asphalt-Rubber, but may substitute a maximum of 3 percent (3%) total binder weight of natural rubber in lieu of any whole scrap tire CRM quantities.
- 600-2.1.5 Type D. Asphalt-Rubber shall be a combination of whole scrap tire CRM, natural CRM (slightly less than Type B), paving asphalt and asphalt modifier conforming to Subsection 600-2.

Memorandum

To:

ALL DISTRICT DIRECTORS

Attention District Materials Engineers

Date: February 28, 1992

File:

From:

DEPARTMENT OF TRANSPORTATION Division of New Technology, Materials and Research

Subject: DESIGN GUIDE FOR ARHM-GG

Attached is a Guide for your use when considering one type of asphalt concrete containing reclaimed tire rubber that is eligible for Federal funding on pavement rehabilitation projects. The Guide contains the procedure we will be using to select asphalt rubber hot mix-gap graded (ARHM-GG) design thicknesses. ARHM-GG is the only type of rubber modified pavement addressed herein because it appears to be the most promising of those we have studied. The use of ARHM-GG as set forth in this Guide should be considered non-experimental. ARHM-GG pavement designs that do not conform to this Guide should, therefore, be considered as experimental. Other types of asphalt concrete containing reclaimed tire rubber are also eligible for Federal funding. However, the data currently available regarding these other mixes is inconclusive. When data supports their routine use, a design guide will be developed for them.

FHWA has approved our proposal to use this Guide. However, it is important to note that this is an Interim Guide and that it will be modified as suggested by the results of current and future research by Caltrans and others. We must, therefore, continue to construct experimental sections based on equivalences other than those implied by this Interim Guide. If you have any questions regarding the use of this Guide, contact Joe Hannon or Jack Van Kirk of my staff at 8-497-2353 and 8-497-2357 respectively.

The attached specifications should be used for ARHM-GG. If you have any questions regarding these specifications, please contact Jack.

Division of New Technology,

Materials and Researchy

Attachments

cc: Bednar - FHWA JMassucco - FHWA BManning - LSR DMayer - OE KMori - OPPD TBressette JHannon JVanKirk

Asphalt Rubber Hot Mix-Gap Graded Thickness Determination Guide (Interim)

Procedure:

- 1. Determine the thickness of conventional DGAC required for the structural needs of the pavement (based on deflections and structural section stiffening using current Caltrans procedures).
- 2. Determine the thickness of conventional DGAC required to retard reflection cracking (using current Caltrans procedure).
- 3. Select a DGAC overlay thickness that satisfies the requirements of 1 and 2 above.
- 4. Use either Table 1 or Table 2 to determine the ARHM-GG equivalent sections, with and/or without SAMIs. Use Table 1 if structural needs control and Table 2 if reflection crack retardation controls.
- 5. If the ride score of the pavement to be rehabilitated is greater than the allowable maximum and there is no structural need per 1 above, select one of the following:
 - a) Place two 0.10' thick lifts of ARHM-GG or
 - b) Cold plane to a depth of 0.10', then place ARHM-GG as determined per Steps 1 thru 4 above.

Table 1 Structural Equivalencies

THICKNESS (ft.)

DGAC	ARHM-GG ¹	ARHM-GG on a SAMI
0.15	0.102	_
0.20	0.10	<u>-</u>
0.25	0.15	0.10
0.30	0.15	0.10
0.35	0.20	0.15
0.40	0.20	0.15
0.45	0.15 ³	0.20
0.50	0.15 ⁴	0.20
0.55	0.20 ³	0.15 ³
0.60	0.20 ⁴	0.15 ⁴

Notes:

- 1. The maximum allowable non-experimental equivalency for ARHM-GG is 2:1.
- 2. The minimum allowable ARHM-GG lift thickness is 0.10'.
- 3. Place 0.15' of new DGAC first.
- 4. Place 0.20' of new DGAC first.
- 5. ARHM-GG may not prevent cold weather induced transverse cracks.

Table 2

Reflection Crack Retardation Equivalencies

THICKNESS (ft.)

DGAC	ARHM-GG	ARHM-GG on a SAMI
0.15	0.101	•
0.20	0.10	•
0.25	0.15	
0.30	0.15	<u> </u>
0.35 ²	0.15 or 0.20 ³	0.104

Notes:

- 1. The minimum allowable ARHM-GG lift thickness is 0.10'.
- 2. A DGAC thickness of 0.35' is the maximum thickness recommended by Caltrans for reflection crack retardation.
- 3 Use 0.15 if the crack width is <1/8" and 0.20 if the crack width is $\ge 1/8$ ".
- Use if the crack width is ≥1/8". If <1/8", use another strategy.
- 5. ARHM-GG may not prevent cold weather induced transverse cracks.

LIMITS INDIANA ST / ROWAN AV INDIANA ST / POMONA FWY POMONA FWY / WOODS AV MAGNOLIA BL / VERDUGO AV FORD BL / MEDNIK AV PALM AV / ORANGE GROVE AV POMONA 60 FWY / GALE AV AVENUE M / AVENUE N ET AL AVENUE M / AVENUE N AVENUE M / AVENUE N	AVENUE E / AVENUE INS AVENUE E / AVENUE I ET AL ET AL ET AL ET AL AVENUE J / AVENUE M8 ET AL AVENUE BL / WILMINGTON AV NORMANDIE AV / VERMONT AV VERMONT AV / 270' W/O NORMANDIE AVENUE M / AVENUE P	MAIN ST / AVALON BL WOODRUFF AV / WESTERN CB SUNSET AV / PUENTE AV TEMPLE AV / NOGALES ST. AMAR/VALLEY ECHELON AV / VALINDA AV MT EMMA RD / MM 2.00 MM 2.00 / SIERRA HWY 1000 E/O GRAND / VALLEY CENTER,AV CITRUS AV / GRAND AV ET AL	STANDRIDGE AV / CHALLENGER WY SOTH ST W / 40TH ST W 170TH ST E / LONGVIEW RD SIERRA HWY / 900' WESTERLY ET AL POMONA FWY / COLIMA RD TEMPLE AV / RAILROAD AV 800' E/O GARFIELD AV / GREENWOOD AV ET AL ET AL
STREET NAME 1ST ST 3RD ST 3RD ST 3RD ST 3RD ST 7TH AV 7TH AV 40TH ST E 48TH ST	2011 ST E 50TH ST E 50TH ST W 52ND ST W 90TH ST E 105TH ST E 150TH ST E 170TH ST E 223RD ST 223RD ST 223RD ST 2240TH ST E	ALONDRA BL ALONDRA BL AMAR RD AMAR RD ANGELES HY II ANGELES HY III ARROW HWY ARROW HWY ARTESIA BL	AVENUE K AVENUE M AVENUE O AVENUE S AVENUE T AZUSA AV BALDWIN PK BL BANDINI BL BARRANCA AV BARRANCA AV
PROJECT YEAR 02 - 94 04 - 92 04 - 93 12 - 93 05 - 96 03 - 95 06 - 95 01 - 96 01 - 94			06 - 92 09 - 95 03 - 94 08 - 96 09 - 93 05 - 95 08 - 95
PROJECT # X7106724 X7106724 X7106727 UBUR4472 X2108583 X2406851 X22407154 X22508427 R3121331	K2506527 R3127274 X2506683 X2508000 R3127273 R3127273 R3121530 R3121558 UCAR7922 X2208010 R3121573	X2208434 UBFL6235 X2106957 UWCV5258 X2107092 R3121547 R3121548 X7506736 X7506737 X2406398	ULAN21111 X2507068 R3121532 X2506680 X2506921 X2408456 UIND6123 R9112438 X2507069
LAB # 35022 34892 35017 35153 35200 35460 35775 35275 35275 35275 35275 35830	35658 34961 35658 34947 35530 35415 35414 35424 35424 35566 35511 35566	35739 35739 35238 35251 35463 35376 35377 34808 35027- 34762	34913 35482 35416 35851 35178 35743 35644 35667 35790

	WALNUT ST / SLY CB	MAPLE AV / MONTEBELLO BL	MONTEBELLO BL / EAST CB	LARGO VISTA RD / BIG ROCK CK RD	VALYERMO KD / 3379 S/O MM 5.29	SOLEDAD CYN / 350' N/O SOLEDAD CYN	BCR N/O SOLEDAD CYN/350' N/O SOLEDA	300'N/O SOLEDAD CYN RD / CENTURION	VALENCIA BL / SOLEDAD CYN RD/ DAVID	800' N/O MAGIC PKWY /SOLEDAD CYN RD	AIRPORT, TAXIWAY, & PARKING	ORANGE FWY / ORANGE COUNTY LINE		ROYAL OAKS DR / SOUTH CB					S/O 120TH ST / 127TH ST		GLADSTONE ST / N/O ARROW HWY	ERCE	FULLERTON RD / BANIDA AV	CASINO DR / WHITTIER N'LY CB	BROADWAY / LEFFINGWELL RD	PARAMOUNT BL / DAIILIA ST	WORKMAN MILL RD / 700 E/O WORKMAN	1260' N SAN GABRIEL CYN RD/SAN GABR	STUDEBAKER RD / EAST COUNTY LINE	DOWNEY AV / CLARK AV	REEVES ST / SANTA FE AV	AVALON BL / CENTRAL AV	ISIS AV / INGLEWOOD AV	SIS AV / NASH ST		BUENA VISTA ST / KEYSTONE ST	VALLEY BLAUPRR & WALNUT/POMONA FWY	WALNUT DR / COLIMA RD	CENTRAL AV / ALAMEDA ST	COMPTON AV / METRO BLUE LINE	PENNSYLVANIA AV / E/O BRIGGS AV	150' W/O EVANWOOD AV / GLENDORA AV	N/O MODONA / COLIMA	COLIMA RD / AGUIRO ST	9TH AV / TURNBULL CYN RD	TURNBULL CYN RD / HACIENDA BL	
IMITS	WALN	MAPLE	MONTE	LARGO	VALYE	SOLED,	BCR N/	300N/O	VALEN	800° N/C	AIRPOF	ORANG	ETAL	ROYAL	ET AL	ET AL	ET AL	ET AL	S/O 120	ET AL	GLADS	COMMERCE	FULLE	CASING	BROAL	PARAN	WORK	1260'N	STUDE	DOWN	REEVE	AVALC	ISIS AV	ISIS AV	ET AL	BUEN	VALLE	WALN	CENTR	COMP	PENNS	150' W/	N/O M	COLIM	9TH A	TURNE	
STREET NAME	BELLFLOWER BL	BEVERLY BL	BEVERLY BL (3B)	BIG PINES HWY	BIG ROCK CK RD	BOUQUET CYN RD	BOUQUET CYN RD	BOUQUET CYN RD	BOUQUET CYN RD	BOUQUET CYN RD	BRACKETT	BREA CYN RD	BRIGGS AV	BUENA VISTA ST	CALOBAR ST	CAMERON AV	CAMINO DEL SUR	CAROLINA PL	CENTRAL AV	CHAGALL ROAD	CITRUS AV	CITY OF	COLIMA RD	COLIMA RD	COLIMA RD	CONSUELO ST	CROSSROADS PKWY	CRYSTAL LAKE RD	DEL AMO BL	DEL AMO BL	DEL AMO BL	EL SEGUNDO BL	EL SEGUNDO BL	EL SEGUNDO BL	ELM AV	EMPIRE AV	FAIRWAY DR	FAIRWAY DR	FIRESTONE BL	FLORENCE AV	FOOTHILL BL	FRANCISQUITO AV	FULLERTON RD	FULLERTON RD	GALE AV	GALE AV	
PROJECT YEAR	- 92	- 85	- 95	96 -	96 -	- 93	- 94	- 94	- 95	- 95	96 -	96 -	96 -	- 95	- 94	- 95	- 93	- 95	- 93	- 95	- 92	96 -	- 93	- 94	96 -	- 95	- 95	- 36	- 93	- 92	- 95	- 93	- 94	- 94	96 -	- 93	- 94	- 95	96 -	- 94	- 95	- 93	- 89	- 93	- 94	- 95	
PROIE	80	60	3	0	5	B	8	12	0	0	05	60	0	10	10	60	01	01	80	0	12	60	80	0	07	05	12	0	03	07	=	0	07	07	0	60	=	12	60	2	0	07	0	07	07	=	
PROJECT #	X2406599	X2302929	X2107005	R3127367	K3127373	USTC2843	USTC5534	USTC5553	USTC5562	USTC5534	GSS80100	X2408436	R3127392	UDUA7502	R3127216	X2507071	X2406836	R3127215	X7206663	R3121572	X7506702	UCMR7771	X2706899	X2406836	X2408437	R5114488	X2108429	R3127400	X2406474	X2406554	X2238194	X7206665	X2207109	X2407177	R3127391	UBUR4467	(JINI)5114	X2406840	X2706992	X2208007	X2506929	X7706648	X2106146	X2406688	X2406842	X2408438	
LAB#	34921	31764	35433	35786	35782	34991	35431	35526	35592	35612	35849	35728	35814	35712	35568	35471	35225	35567	35025	35542	35032	35895	35164	35291	35751	35629	35723	35820	34813	34880	35632	35026	35441	35505	35818	35142	35581	35729	35282	35565	35180	35019	34461	34977	35197	35730	

LIMITS RWINDALE AV / AZUSA AV 838' W/O BARRANCA AV / BARRANCA AV PUENTE ST / ROWLAND ST ARROW HWY / CIENEGA AV	PUENTE ST / HURST ST SLAUSON AV / BANDINI BL AVOCADO CREST RD / ORANGE CNTY LINE THORNTON AV / VICTORY BL MT VERON DR / PALMERO BL HOLLY AV / SANTA CLARA ST SANTA GERTRUDES/ ORANGE COUNTY LINE SHOEMAKER AV / CARMENITA RD ET AL	AGOURA RD / TUNNEL NO. 3 CULVER CB / LOS ANGELES CB LEFFINGWELL RD / ORANGE COUNTY LINE ET AL BIG PINES HIGHWAY / FORT TEJON RD GLADSTONE ST / ARROW HWY BALDWIN / MUSCATEL WEST CB / EAST CB CARMENITA RD / MEYER RD 300° E/O TELEGRAPH RD/ LA MIRADA BL	ET AL MULHOLLAND HIGHWAY / VENTURA CTY LN EAGLEHELM DR/ CRYSTAL SPRINGS RD ET AL W/O ADUANA DR / PECK RD ET AL ET AL GOLDEN STATE FWY / VALLEY ST I-5 / VALENCIA BL VICTORIA ST / CARSON ST EL SEGUNDO BL / ROSECRANS AV ET AL	ALTADENA DR / 630° S/O WOODBURY RD SEPULVEDA BL / AVIATION BL HASTINGS AV / LEFFINGWELL RD COLORADO BL / CALIFORNIA BL STOKES CANYON RD / COLD CANYON RD DECK E/O I-5/BCR E/O SINGING HILLS MAGIC MOUNTAIN PKWY/AVENIDA NAVARRE VINELAND AV / SUNSET AV GARVEY AV / HELLMAN AV CHOISSER ST / SLAUSON AV
STREET NAME GLADSTONE ST GLADSTONE ST GRAND AV GRAND AV	GRAND AV GREENWOOD AV HACIENDA BL HOLLYWOOD WY HOMELAND DR HUNTINGTON DR E IMPERIAL HWY IMPERIAL HWY	KANAN RD LA CIENEGA BL LAMBERT RD LAMBERT RD LARGO VISTA RD LARK ELLEN AV LAS TUNAS DR LAS TUNAS DR LEFFINGWELL RD	LIGHT ST LIL SYCAMORE CN LIVE OAK SPRING LOMA ALTA DR LONGDEN AV LONGBEN AV LONGWORTH AV LYONS AV MAGIC MTN PKWY MAGIC MTN PKWY MAIN ST MAIN ST	MARENGO AV MARINE AV MEYER RD MICHILINDA AV MULIOLLAND HWY MGEAN PKWY MGEAN PKWY NELSON AV NELSON AV NORWALK BL
PROJECT YEAR 10 - 95 09 - 96 08 - 95 05 - 94			01 - 56 03 - 56 04 - 95 04 - 95 05 - 95 06 - 95 07 - 96 08 - 96	06 - 95 12 - 95 02 - 93 03 - 92 01 - 94 11 - 94 09 - 95 06 - 93
PROJECT # X2107099 X2108430 X2506930 X2506930	X2506930 R9112438 X2408459 UBUR7386 X2208451 UARC7505 X7406707 X2106904	X2306757 X2206911 X2406846 R3127326 R3127370 X2106016 X2506807 UTEM2961 X7106652	R3127357 R3127352 USTC6566 R3121277 R3127255 FX50861 USTC2843 USTC5570 UCAR2693 X2206501	X2507081 X2408501 X2106653 X7506708 X2306686 USTC5534 USTC5533 UIND6138 X2306289 X2102031
15464 35724 35181 35181	35586 35069 35752 35687 35748 35748 34915 35113	28475 35108 35213 35770 35784 34495 35006 35021	35776 35776 35830 35826 35880 35880 35837 34987 34882 34894	35448 35765 34951 34834 34969 35428 35525 35695 35695 35695 3695

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LIMITS 166TH ST / ALONDRA BL GOODRUCH BL / SIMMONS AV NELSON AV / S.P.R.R. & PALM AV @ 3RD ST / GLENOAKS BL McBEAN PKWY / LYONS AV STOCKER ST / SLAUSON AV ET AL 215TH ST E / 2.5 MI ELY SANTA CLARITA RD / TARYN DR	ET AL VALLEY BL / 6TH AV 445' S/O FRANCISQUITO / NELSON AV ET AL RAMONA BL / VALLEY BL MCBEAN PKWY / VALENCIA BL ET AL E/O BUTLER AV / FRAILEY AV SEPULVEDA BL / REDONDO AV BLOOMFIELD AV / 1-5 N/B OFFRAMP GREENBANKS AV / DUARTE CB BURBANK BL / GRISMER ST ET AL	BKUNGHAM AVY WILSTILKE DE NORTHI / SOUTHI CB S/O FAWCHT AV / DUINFIEL STY RUSH ST WOODBURY RD / ALTADENA DR 350° S/O LIVE OAK AV / GRAND AV ARHM - AUDIT CORING COPPER HILL DR/1000'S/O COPPER HILL WILSHIRE BL / CONSTITUTION AV S/O WILSHIRE BL / OHIO AV AMAR RD / NOGALES ST ET AL IMPERIAL HWY / MEYER RD	AVENUE S/BARKEL SPRINGS IN ANGELES FOREST HWY / AVENUE T SANTA CLARITA C.B. / L.A. C.B. VASQUEZ CYN RD / MINT CYN RD FRIENDLY VLLY/800WHISPERING LEAVES SOLEDAD CYN RD / 800N/O WHISPERING ANGELES FOREST HWY / AVENUE T 1970W/O YUCCA RIDGE/920°E/O BARRAN WIL.MINGTON AV / STATE ST 3700 N/O SYCAMORE CK/5300° S.A.F.B ELIZABETH LAKE RD/8468° N/O CAMP 14 5400°E/O BOUQUET CYN/90°E/O LANDSID
STREET NAME NORWALK BL OLYMPIC BL ORANGE AV ORANGE GROVE ORCHARD VILLAGE OVERHILL DR PAINTER AV PALMDALE BL	PINEGLEN RD PROCTOR AV PUENTE AV RAMONA AV RIO HONDO ROCKWELL CYN RD ROOKS RD ROSECRANS AV ROSEC	SAN VICENTE BL SAND CYN RD SANTA ANITA AV SANTA ANITA AV SANTA ANITA AV SANTA CLARITA SECO CYN SEPULVEDA BL SEPULVEDA BL SHINN RD SHINN RD	SIERRA HWY SIERRA MADRE AV SLAUSON AV SN FRANCISQUITO SN FRANCISQUITO SOLEDAD CYN RD
PROJECT YEAR 08 - 94 04 - 93 09 - 95 01 - 95 11 - 93 09 - 95			06 - 96 10 - 93 01 - 95 01 - 95 06 - 95 09 - 95 10 - 89 01 - 96 01 - 96
PROJE 08 04 09 09 01 01 11		200000	
PROJECT # UNWK 5099 R9112438 UIND6136 UBUR 1479 USTC5562 X2208008 X2706850 X2506936 USTC6970	R3127398 UIND4095 X2106494 R3127390 URMD6319 USTC2843 R312720 X2206502 X2406814 UNWK 5099 UDUA6152 UBUR7384	X2306865 USIC5534 X2106654 R3121459 X7507084 USTC6578 USTC5562 X2306200 X2306200 X2306868 UWCV6913 R3127399	X2506680 X2506939 R8315646 R8315301 USTC6580 USTC6970 X2506929 X2708431 X2106226 R3127374 R3127366
LAB# 35497 35497 35693 35699 35609 35194 35194	35.702 35.823 35.823 34.849 35.885 34.891 35.83 35.83 35.83 35.83 35.83 35.83 35.83	35109 35611 34952 35260 35475 3559 35591 3509 3509 3509 3509 3509 3509	34959 35204 35544 35606 35707 35707 35725 34557 34557 34589

	BOUQUET CYN / 320' E/O BOUQUET CYN	LANG STATION RD / AGUA DULCE CYN RD	BCR E/O SIERRA HWY/BCR W/O LOST CYN	BCR E/O BOUQUET / 300' E/O BOUQUET	MISS GRACE / SAND CANYON RD	SIERRA HWY / SANTA CLARITA CB	GILLESPIE AV / SIERRA HWY	BOOTLEGGER CYN RD / GILLESPIE AV	BE/INDIAN CK/0873 BOOTLEGGER CYN RD	WILLOWBROOK AV / MONA BL	DEL AMO BL / GRIDLEY RD	SCHUEREN RD / MULHOLLAND HWY	4,500 E/O GRAND / 8,600 E/O GRAND	400' E/O VINELAND AV / PUENTE AV	SUNSET AV / HACIENDA AV	PUENTE AV /ORANGE AV		0.8 MI N/O / 5.4 MI N/O TEMPLIN HWY	PINE CYN RD / 4832 N/O LANCASTER RD	McBEAN PKWY / 760 S/O GOLFVIEW DR	INDIANA ST / MARIANA AV	BCR E/O BOUQUET / 700' W/O BOUQUET	SANTA ANA FWY / McBEAN PARKWAY	SUZANNE RD / WEST COVINA CB	HAMBLEDON AV / 2250' E/O LASEDA RD	TURNBULL CYN RD / PROCTOR AV	SN GABRIEL RIVER / TURNBULL CYN RU	BADILLO SI / ARKOW HW (MANHAITAN BEACH BL / 32ND FL	TELEGIKAPH KD/LEFFINGWELL KU	LA JOUR WI / FOOTBLE BE	N DE / 1711 SO BOIN BOIN		2075N/O DRAYFR I N/25N/O DRAYER LN	350 W/O INDIANA ST / AYERS AV	ATI ANTIC BL / 100' W/O EASTERN AV	90' F/O EASTERN AV / SANTA ANA FWY	SAN GABRIEL RIVER / PIONEER BL	SAN GARRET RIVER/100F/O CROWNDALE	ACHBODO / COLEDAD CVN RD	SOLEDAD CITATION OF THE STATE O	AVENIDA CAPPELAJORCHARD COUNTY LINE	BCR W/O ORCHARD V/BCR W/O AVENIDA C	AVENIDA CAPPELA / LYONS AV	200'S/O VICTORIA AV/UNIVERSITY DR	
LIMITS	BOUQUETCY	LANG STATIO	BCR E/O SIERF	BCR E/O BOUC	MISS GRACE /	SIERRA HWY /	GILLESPIE AV	BOOTLEGGER	BE/INDIAN CK	WILLOWBROC	DEL AMO BL	SCHUEREN RI	4,500' E/O GRA	400' E/O VINEI	SUNSET AV	PUENTE AV /	ET AL	0.8 MI N/O / 5.			INDIANA ST /	BCR E/O BOU	SANTA ANA I	SUZANNE RD	HAMBLEDON	TURNBULL C	SN GABRIEL	BADILLOSI			LA IOUK WI	WASHING IO	ET AL				•				CANTIDATE	AVENIDA CA	BCK W/O UK			ET AL
STREET NAME	SOLEDAD CYN RD	SOLEDAD CYN RD	SOLEDAD CYN RD	SOLEDAD CYN RD	SOLEDAD CYN RD	SOLEDAD CYN RD	SOLEDAD CYN RD	SOLEDAD CYN RD	SOLEDAD CYN RD	STOCKWELL ST	STUDEBAKER RD	STUNT RD	TEMPLE AV	TEMPLE AV	TEMPLE AV	TEMPLE AV	THE OLD ROAD	THE OLD ROAD	THREE POINTS RD	TOURNAMENT RD	UNION PACIFIC	VALENCIA BL	VALENCIA BL	VALLEY BL	VALLEY BL	VALLEY BL	VALLEY BL	VALLEY CTR AV	VALLEY DR	VALLEY VIEW AV	VERDUGO BL	VIA MAKINA	VINELAND AV	WALMET GROVE AV	WASHINGTON BI	WASHINGTON BL	WASHINGTON BL	WASHINGTON BI	WASHINGTON BL	WASHIING LOIN BL	WILLESCINK	WILEY CYN RD	WILEY CYN RD	WILEY CYN RD	WIL MINGTON AV	WOODS AV
PROTECT YFAR	04 - 93	•	12 - 94	12 - 94	12 - 94	12 - 94	05 - 95	05 - 95	05 - 95	02 - 95	. 96	11 - 92	01 - 93	08 - 95	08 - 94	02 - 96	03 - 95	96 - 90	07 - 96	07 - 95	01 - 95	12 - 94	02 - 95	96 - 60	16 - 11	11 - 93	•	•	•	•	•	•	٠	03 - 50	•	•			,	•	•	•	•	•	٠	96 - 10
DDOIECT# D	243	X2506941	USTC5534	USTC5534	USTC5553	R8315318	R3127278	R3127277	R3127276	X2207118	X2408580	X2306673	X2506681	X2107103	X2108003	X2108575	X2506682	X2508605	R3127372	USTC6580	X2108026	USTC5534	USTC5562	X2106256	X7106723	UIND4058	X2107104	X2507087	X2408500	X2406852	X2508041	X2408440	K3127395	K312/369	A2108432	K9112438	R9112436	K9112436	X240/132	X2708433	USTC5562	USTC2843	USTC5534	USTC5562	X2208435	R3127328
4 Q V				35429	35527	35540	35654	35655	35656	35480	35855	34971	34962	35434	35518	35835	34960	35867	35783	35670	35509	35430	35593	34588	34837	35231	35435	35474	35766	35116	35623	35727	35827	35789	97/55	55075	33070	33077	35459	35738	35610	34986	35427	35594	35740	35772

LIST OF COMPLETED PROJECTS FOR 1996 WITH ASPHALT RUBBERIZED HOT MIX (ARHM)

JOB NUMBER	CC NO.	PROJECT NAME	<u>UNIT</u>	QUANTITY
R3127274	7274	50th Street East	Ton	1,194.59
R3127273	7273	90th Street East, et al	Ton	5,589.98
R3127216	7216	Calobar Avenue, et al	Ton	3,177.64
R3127215	7215	Carolina Place, et al	Ton	2,835.92
X2406474	6474	Del Amo	Ton	5,692.00
X2407177	7177	El Segundo Boulevard	Ton	2,825.50
X2106016	6016	Lark Ellen Avenue	Ton	478.00
X2506807	6807	Las Tunas Drive	Ton	3,220.00
R3127327	7327	Light Street, et al	Ton	5,688.00
X2408580	8580	Studebaker Road, et al	Ton	2,447.80
X2108003	8003	Temple Avenue	Ton Total =	3.050.44 36.199.87

ASPHALT RUBBER COST SAVINGS

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Required: 4" AC overlay or 2" ARHM
Quantities for a 12' lane:
2" ARHM = 1' X 2"/12" X 12' X 145 lbs/SF = 290 lbs/lin ft
4" AC = 1' X 4"/12" X 12' X 145 lbs/SF = 580 lbs/lin ft
2" ARHM = 0.145 Tons/ft of 12' wide lane
4" AC = 0.290 Tons/ft of 12' wide lane
1 mile = 5280'
5280 X 0.145 = 765 Tons/lane mile
                                       ARHM
5280 X 0.290 = 1530 Tons/lane mile
                                        AC
ARHM = $45 per Ton
 AC = $30 per Ton
 765 \times $45 \times 2 = $68,850 ARHM/mile
1530 \times $30 \times 2 = $91,800
                           AC /mile
Pavement prep for AC = $6,336/mile (L.A. County average)
               $91,800
               + 6,336
               -68,850
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Savings per mile = \$29,286

ASPHALT RUBBER

Common Construction Problems

- 1. Density HE have had problems getting 95% compaction.
 - a) Make sure temperature behind -ne paver is over 290° F
 - b) Use 2 breakdown rollers finish rolling is not critical.
 - c) Discourage use of bottom dumps. It is difficult to maintain heat in windrows,
- 2. Tracking
 - a) Do not let truffic on the new mot until temperature drops below 90°F on the surface.
 - b) Use blotter sand on a warm mat if traffic must use it.
 - c) Spraying water on the warm mat helps bring the temperature down and avoid sanding.
- 3. We have not had mix or plant problems.

PRESENTATION MATERIALS Rubberized Asphalt Concrete

DAVID STRASSMAN

DRS Ltd.



CRUMB RUBBER CONFERENCE MONTEREY, CALIFORNIA MAY 23, 1997.

GREETING:

Welcome, Ladies and Gentlemen. My name is Dave Strassman from D.R.S., Limited. of Madison, Wisconsin. The city of Madison has been recently voted the #1 city of the country in which to live. And, of course, Wisconsin is home to the Superbowl Champion Green Bay Packers.

WINTER PAVING - Slide 1

Temperature variations provide unique challenges to the paving industry in Wisconsin and the upper midwest versus California and areas of the country that do not experience harsh winter weather conditions. We typically have 20-25 freeze/thaw cycles during a winter season.

These constant changes require that asphalt is flexible, yet stable. Using crumb rubber and fiber as additives in asphalt improves both of these qualities. Flow rates are 30-35% greater while stability is 30% greater.

DRY RUBBER PROCESS

We have been using rubber as an aggregate in asphalt since 1991. This is referred to as the "dry rubber process". We purchased crumb rubber from outside suppliers until 1995, when we developed our own grinding system. We now contract with local cap shops to pick up their waste tire buffings. We processed and incorporated into asphalt more than 500,000 lbs. of rubber in 1996.

PLANT INPUT - Bin Slides

The crumb rubber is held in a modified grain bin and is moved by an auger to a weigh hopper before it is added to the asphalt mix. The fiber, after being weighed, is blown directly into the pug mill by a modified insulation blower, in the dry cycle. The introduction of the rubber and fiber, as well as the other aggregates, is facilitated by a computer-controlled batching process. This insures a consistent mix design and documents the batches.

CRUSHING RECYCLED MATERIAL

In addition to increased flexibility and stability, rubberized asphalt is environmentally-friendly in that it makes use of waste tires and fiber products. The asphalt itself is also recyclable. Using a crusher, the asphalt slabs are ground into a fine material which can again be used as an aggregate in asphalt, or as a base material for paving projects.

APPLICATIONS FOR RUBBERIZED ASPHALT

The rubberized asphalt mix that we have designed has been used on Class A Highways in Dane and Outagamie counties in Wisconsin. Other uses include airport runways (Blackhawk Airfield) and heavy industrial including projects for Marshall Erdmann Co. and Waste Management. The extended life of asphalt is important in commercial applications where downtime must be minimized. We have also used rubberized asphalt on farm drives (mapping cracks) and running tracks (design changes). We even used this mix at a golf course on cart paths, laying the asphalt on a dirt base, as opposed to the conventional gravel base.

WHAT'S NEW FOR 1997

Rubberized mix works beautifully for textured asphalt such as StreetPrint. The hot asphalt (160 degrees) is imprinted to look like brick. Using an infrared heating unit, this process may also be performed on existing asphalt. After imprinting, the surface is treated with a cement-reinforced acrylic color coat. An option to the color coating is to sandblast the imprinted surface, which exposes the aggregate. This is a no-maintenance alternative which is about one-third of the cost of the acrylic coating.

CLOSING:

Rubberized asphalt works, it is fun, and it is easy.

Thank you, everyone, for your time and I wish you
all success using crumb rubber.

PRESENTATION MATERIALS Rubberized Asphalt Concrete

JAGKVAN KIRK

Caltrans

CALTRANS PAVEMENT REHABILITATION USING RUBBERIZED ASPHALT CONCRETE

by
Jack L. Van Kirk, P.E.
Senior Materials and Research Engineer

California
Department of Transportation
office of transportation materials and research
5900 Folsom Boulevard
Sacramento, CA 95819
(916) 227-7300

Presented at a meeting of the

Rubber Division, American Chemical Society

Anaheim, California

May 6-9, 1997

CALTRANS PAVEMENT REHABILITATION USING RUBBERIZED ASPHALT CONCRETE

by
Jack L. Van Kirk
Senior Materials and Research Engineer

ABSTRACT

Caltrans has considerable experience with the use of recycled rubber in asphalt concrete (AC). This experience began in 1978 and has continued to the present. The experience to date has shown that the use of rubber in asphalt concrete can be cost effective.

On the early projects, Caltrans compared equal thicknesses of rubberized asphalt concrete (RAC) to conventional AC. The RAC has outperformed the conventional mixes on these projects and most of these projects are still in service. In 1983, a project was constructed using reduced thickness RAC (as compared to the design thickness for the conventional AC). This project has shown that thinner sections of RAC can outperform thicker sections of conventional AC.

In February 1992, Caltrans developed an Interim Design Guide for RAC. This design guide, which was approved by FHWA, allows routine usage of RAC as an approved rehabilitation strategy for pavements in California. Since this guide was approved, the use of RAC has significantly increased in California. However, in 1993 and 1994, there were complaints of illness by workers on Caltrans projects. Caltrans has conducted air emissions testing on over 15 projects beginning in 1993. Testing to date has shown that acceptable worker exposure levels have not been exceeded on these projects. Caltrans is working with industry via a permanent standing committee to improve and refine the RAC specifications.

INTRODUCTION

The California Department of Transportation (Caltrans) has been using rubber-modified asphalt concrete or rubberized asphalt concrete (RAC) for over 19 years. The first project using RAC was constructed in 1978 and since then Caltrans has had considerable experience with RAC. This experience has not only included field trials of RAC, but it also has included research in the laboratory. Caltrans has constructed over 130 rehabilitation (overlay) projects using RAC overlays. These projects have included different types of rubber modification. All but three projects utilized recycled granulated tire rubber. There were seven projects that used a dry process, where the recycled rubber is added to the aggregate before the asphalt is added. All other projects used a wet process, where the recycled rubber is first blended and reacted with the asphalt, to form asphalt-rubber binder, before being added to the aggregate. This wet process has proved to be the most cost effective use of recycled rubber in asphalt concrete.

Overall, Caltrans rehabilitation program has proved quite successful. However, in the snow regions where tire chains are used, the design life was not being achieved when using conventional dense graded asphalt concrete (DGAC), thereby resulting in increased maintenance costs. In 1978, in its quest to find a more durable mix for the snow region, Caltrans began experimenting with RAC mixes. Later laboratory research indicated that RAC mixes were more abrasion resistant when compared to conventional DGAC. Field permeability testing also showed that RAC mixes had extremely low permeabilities. It was felt that these low permeabilities would reduce the infiltration of water into the mat and therefore cut down on the freeze-thaw damage. The low permeabilities should also reduce oxidation and thereby lower the aging rate. Because of the success in the snow region Caltrans began to broaden its use of RAC mixes.

BACKGROUND

On the RAC projects constructed by Caltrans prior to 1983, the RAC was compared to equal thicknesses of conventional DGAC. However, in 1983 a project was constructed (on RT. 395 in northeastern California) using various overlay strategies including three test sections of reduced thickness RAC (when compared to the conventional DGAC overlay design thickness). Also placed on the project were various thicknesses of conventional DGAC. This project, though not realized at the time, later became the turning point for Caltrans rehabilitation strategies involving RAC mixes. For awhile after 1983, Caltrans continued to construct and compare equal thicknesses of RAC and conventional DGAC on other projects, while reviewing and accumulating data

overlays of RAC, when compared to conventional DGAC, could provide a longer service life at a reduced cost. At this point in time, Caltrans strategy for RAC test section overlays changed. It was decided that all subsequent projects if appropriate would involve RAC overlays that were thinner than those required if conventional DGAC were used. Projects utilizing reduced thicknesses continued until 1992. At that time the use of reduced thickness RAC became a routine strategy in the Caltrans rehabilitation program.

TYPES OF RAC USED BY CALTRANS

Caltrans rehabilitation projects using RAC overlays have included rubber modified: dense graded asphalt concrete (DGAC), open graded asphalt concrete (OGAC), gap graded asphalt concrete (GGAC), and an Arizona-type, three-layer system. These overlays have been placed over flexible pavement (AC) as well as rigid pavement (PCC). On these projects, six different types of RAC have been used: devulcanized reclaimed rubber has been added using a dry process to conventional DGAC mix; vulcanized reclaimed tire rubber has been added using a dry process to a gap-graded aggregate and conventional asphalt; and vulcanized reclaimed tire rubber has been preblended with a conventional asphalt to form asphalt-rubber binder (wet process) which was then added to a dense graded, open graded or gap graded aggregate; or the binder was used with a pre-coated chip as a stress absorbing membrane interlayer (SAMI) in an Arizona-type, three-layer system. SAMIs also have been used with other RAC mixes. Currently, Caltrans uses predominantly gap graded RAC mixes in their rehabilitation program.

OVERLAY DESIGN

Caltrans uses a deflection-based design procedure for rehabilitation of flexible pavements. This procedure is also used for RAC overlays. On the early RAC projects, the RAC overlay design thickness was the same as that provided from the deflection study for conventional DGAC. The design life normally used is ten years, and during this time only minor maintenance is expected.

In 1992, Caltrans presented a proposal to the Federal Highway Administration (FHWA) to allow the use of reduced thickness RAC overlays as an approved strategy on federally funded rehabilitation projects. This proposal was approved based primarily on the successful field experience of reduced thickness RAC projects. At that time an Interim Thickness Determination

Guide for asphalt-rubber hot mix-gap graded (attached as Appendix A) was developed and also approved by the FHWA. This guide is considered an interim guide because it will be modified as suggested by the results of current and future research by Caltrans and others.

A different approach is used for PCC pavement rehabilitation involving DGAC overlays. In order to try and obtain the desired ten year design life, the early approach (prior to 1982) was to place a DGAC overlay 75 mm to 150 mm in thickness depending on the condition of the existing PCC pavement. However, the 10-year design life was not being achieved. After 1983, this strategy changed. PCC pavements are now cracked and seated, a leveling course of DGAC is placed, a pavement reinforcing fabric (PRF) is placed, and finally the pavement is overlayed with DGAC 75 mm thick placed in two lifts. This same approach is used for RAC overlays over PCC pavements. However, the PRF is replaced with a SAMI and the 75 mm thick DGAC is replaced with a 45 mm thick RAC overlay. This is referred to as an Arizona-type, three layer system. The RAC is usually a gap-graded or open graded mix.

MIX DESIGN

The Hveem mix design is used by Caltrans for all RAC mixes with a few minor changes. The mix and compaction temperature is increased. The required aggregate temperature is between 149 C and 163 C. The required compaction temperature for the combined mix is between 144 C and 149 C. The Hveem stability requirement is lowered to a minimum value of 23. The asphalt-rubber binder which is supplied by the contractor is added to aggregate meeting the same grading and quality requirements used for conventional DGAC. The binder content for open and dense graded RAC mixes is normally about 20% higher than that for the conventional DGAC mixes and the binder content for gap-graded mixes is normally about 40% higher than that for the conventional DGAC mixes.

COST ANALYSIS

The cost of asphalt-rubber binder is about two and one-half times the cost of conventional asphalt. This increases the cost per ton of RAC by about 30%-40% over that of conventional DGAC. Most of the RAC projects constructed by Caltrans in the past have involved fairly low tonnages of RAC and, as a result, the cost for the asphalt-rubber binder has been relatively high. However, after Caltrans began using RAC routinely, there was a significant reduction in the cost of asphalt-rubber binder. Caltrans experience

has shown that RAC overlays are cost effective when used in reduced thicknesses (when compared to conventional DGAC).

CONSTRUCTION

The construction of the Caltrans RAC overlays has been very similar to that of conventional AC overlays, although there are a few important differences. First, the mix must be placed at a higher temperature, preferably in a range between 149 °C and 163 °C. Raking should be completed before the mix drops below 144 °C. As the mix cools, it becomes stiffer and raking becomes very difficult. Breakdown rolling should be completed before the mix drops below 144 °C. If the mix is compacted at 144 °C or above, excellent relative compaction has usually been achieved quite easily. Values of 96% to 98% relative compaction (compared to a laboratory compacted briquette) are quite common for dense graded RAC. However, compaction of gap-graded RAC has been more difficult because the mix cools faster than conventional DGAC. If proper temperatures are used, adequate compaction can be achieved.

RAC EXPERIENCE

Caltrans has used RAC mixes in many parts of the state and in different climate regions. Many of the early projects were placed to resolve specific problems such as abrasion resistance, OGAC night placement, thin flexible bridge overlays, and desert AC pavement rehabilitation. Generally, control sections containing conventional DGAC were placed on the early projects so that direct comparisons could be made.

RAC mixes have been used on bridge decks, roadside rests, parking lots, and low, medium and high volume roadways. Over the years RAC mixes have proved to provide cost effective performance in all regions of the State.

AIR EMISSIONS PROBLEMS ON RAC PROJECTS

In 1993, there were a number of RAC projects where workers complained of illness while working on the job. Since 1993, Caltrans has collected industrial hygiene data on more than 15 RAC paving projects. This data was collected through the paving contractors to evaluate the health and safety risks of the product. Personal air sampling pumps were worn by individuals (1) dumping the hot mix in front of the paver and (2) on the paver screed. Air samples for asphalt rubber fume measurements were taken at the rear of the paver near the screed and just above the paver auger. These were considered to be worst case (highest concentration) locations. The collected data indicates

that employee exposures during paving are below Cal-OSHA allowable limits. Based on these results, exposure to RAC fumes would not pose a long term or chronic health risk. However, based on incidents of health complaints from the past paving season, short term or acute health effects still can occur. These complaints appear to be related to a combination of the amount of asphalt fume (smoke) generated by the paving operation and personal sensitivities to that smoke. Since it was concluded that there is a direct relationship between mix temperature, smoke and complaints, in January 1994, RAC specifications were changed to lower mix temperatures (from 177 C to 163 C measured at the plant). As a result of this change, there were no reported complaints in 1995. However, health complaints were again reported in the 1996 paving season. As a result of these complaints, further research will be conducted to determine the cause of the complaints.

SUMMARY

Caltrans has had considerable experience with RAC mixes. From this experience, it has been learned that when compared to conventional DGAC, RAC can tolerate higher deflections. RAC mixes have shown that they can outperform substantially greater thicknesses of conventional DGAC. They can exhibit lower permeabilities which in turn decreases oxidation and aging. They have also proven to be more abrasion resistant in the snow regions and when distress does develop it progresses at a much slower rate. All these desirable qualities that RAC mixes possess lead to decreased maintenance costs and ultimately lower annual equivalent costs.

However, if health complaints continue on future projects the use of RAC will be jeopardized. Even though it has been shown that the use of RAC mixes do not pose a chronic health hazard, research on the cause of these complaints will continue until they have been resolved.

At this time, Caltrans believes rubber modified asphalt concrete mixes will probably play a major role in the rehabilitation of rigid and flexible pavements in the future. The role that RAC mixes will play depends on their performance on recently completed projects and projects to be constructed in the next few years. If reduced thickness RAC continues to show the success that has been demonstrated on earlier projects and the health complaints are eliminated, there will be a definite increase in the usage of the product.

DISCLAIMER

The contents of this paper do not necessarily reflect the official views or policies of either the Federal Highway Administration or the State of California. They reflect the views of the author, who is responsible for the facts and accuracy of the data presented herein. Also, neither the State of California nor the United States Government endorse products or manufacturers. Trade and manufacturers names are presented herein because they are considered essential to the objective of this paper.

APPENDIX A

Asphalt Rubber Hot Mix-Gap Graded Thickness Determination Guide (Interim)

Procedure:

- 1. Determine the thickness of conventional DGAC required for the structural needs of the pavement (based on deflections and structural section stiffening using current Caltrans procedures).
- 2. Determine the thickness of conventional DGAC required to retard reflection cracking (using current Caltrans procedure).
- 3. Select a DGAC overlay thickness that satisfies the requirements of 1 and 2 above.
- 4. Use either Table 1 or Table 2 to determine the ARHM-GG equivalent sections, with and/or without SAMIs. Use Table 1 if structural needs control and Table 2 if reflection crack retardation controls.
- 5. If the ride score of the pavement to be rehabilitated is greater than the allowable maximum and there is no structural need per 1 above, select one of the following:
 - a) Place two 0.10' thick lifts of ARHM-GG or
 - b) Cold plane to a depth of 0.10', then place ARHM-GG as determined per Steps 1 thru 4 above.

Table 1 Structural Equivalencies

THICKNESS (FL)

DGAC	ARHM-GG ¹	ARHM-GG on a SAMI
0.15	0.10 ²	•
0.20	0.10	•
0.25	0.15	0.10
0.30	0.15	0.10
0.35	0.20	0.15
0.40	0.20	0.15
0.45	0.15 ³	0.20
0.50	0.154	0.20
0.55	0.20 ³	0.15 ³
0.60	0.204	0.15 ⁴

Notes:

- 1. The maximum allowable non-experimental equivalency for ARHM-GG is 2:1.
- 2. The minimum allowable ARHM-GG lift thickness is 0.10'.
- 3. Place 0.15' of new DGAC first.
- 4. Place 0.20' of new DGAC first.
- 5. ARHM-GG may not prevent cold weather induced transverse cracks.

Table 2

Reflection Crack Retardation Equivalencies

THICKNESS (ft.)

DGAC	ARHM-GG	ARHM-GG on a SAMI	
0.15	0.10 ¹	•	
0.20	0.10	•	
0.25	0.15	•	
0.30	0.15	•	
0.35 ²	0.15 or 0.20 ³	0.104	

Notes:

- 1. The minimum allowable ARHM-GG lift thickness is 0.10'.
- 2. A DGAC thickness of 0.35' is the maximum thickness recommended by Caltrans for reflection crack retardation.
- 3 Use 0.15 if the crack width is <1/8" and 0.20 if the crack width is $\geq 1/8$ ".
- 4. Use if the crack width is $\ge 1/8$ ". If <1/8", use another strategy.
- 5. ARHM-GG may not prevent cold weather induced transverse cracks.

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AN OVERVIEW OF CALTRANS EXPERIENCE WITH RUBBERIZED ASPHALT CONCRETE

by

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AN OVERVIEW OF CALTRANS EXPERIENCE WITH RUBBERIZED ASPHALT CONCRETE

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ABSTRACT

Caltrans has considerable experience with the use of rubber in dense graded asphalt concrete hot mix (DGAC). This experience began in 1978 and has continued to the present. The experience to date has indicated that the use of rubber in asphalt concrete can be cost-effective.

On the early projects, Caltrans compared equal thickness of rubberized asphalt concrete (RAC) to conventional DGAC. The RAC has outperformed the conventional mixes on these projects, but the question of cost-effectiveness is difficult to answer since most of the projects are still in service. In 1983, a project was constructed using reduced thickness RAC (as compared to the design thickness for the conventional DGAC). This project, which is still being evaluated, has shown that thinner sections of RAC can outperform thicker sections of conventional DGAC. But the question that remains is what reduction in thickness can be made and still provide the desired service (design) life.

Caltrans is presently working with the Federal Highway Administration (FHWA) to remove the experimental classification for one type of RAC when used for mitigation of reflective cracking. However, further research is necessary to determine the structural equivalency for RAC.

Caltrans will continue to construct additional projects which will compare reduced thickness RAC to conventional DGAC. These projects are expected to provide field data in the near future to help determine what reduction in thickness is appropriate when using RAC. An increase in the use of RAC is anticipated in the near future. However, once the structural equivalency of RAC is determined, more widespread usage is expected.

INTRODUCTION

The California Department of Transportation (Caltrans) has been using rubber-modified asphalt concrete (RAC) for more than ten years. The first project using RAC was constructed in 1978 and since then Caltrans has had considerable experience with RAC. This experience has not only included field trials of RAC, but it has also included research in the laboratory (1). Caltrans has constructed more than 20 rehabilitation (overlay) projects using RAC overlays. These overlays have included various types of asphalt concrete (AC).

Overall Caltrans rehabilitation program has proved quite successful. However, in the snow regions where tire chains are used, the design life was often not being achieved when using conventional DGAC, thereby resulting in increased maintenance costs. In 1978, in its quest to find a more durable mix for the snow region, Caltrans began experimenting with RAC mixes. Later laboratory research (1,2,3) indicated that RAC mixes were more abrasion resistant when compared to conventional DGAC. Field permeability testing (3) also showed that RAC mixes have extremely low permeabilities. It was felt that these low permeabilities would reduce the infiltration of water into the mat and therefore cut down on the freeze-thaw damage. The low permeabilities should also reduce oxidation and thereby lower the aging rate. Because of the success in the snow region, Caltrans began to broaden its use of RAC mixes.

BACKGROUND

On the RAC projects constructed by Caltrans prior to 1983, the RAC was compared to equal thicknesses of conventional DGAC. However, in 1983, a project was constructed (on Route 395 in northeastern California) using various overlay strategies including test sections of reduced thickness RAC (when compared to the conventional DGAC overlay design thickness). Also placed on the project were various thicknesses of conventional DGAC. This project, though not realized at the time, later became the turning point for Caltrans rehabilitation strategies involving RAC mixes. For awhile after 1983, Caltrans continued to construct and compare equal thicknesses of RAC and conventional DGAC on other projects, while reviewing and accumulating data on the Route 395 project. By 1987, it became evident that substantially thinner overlays of RAC, when compared to conventional DGAC, could provide a longer service life at a reduced cost. At this point in time, Caltrans strategy for RAC test section overlays changed. It was decided that all subsequent projects, if appropriate, would involve RAC overlays that were thinner than those required if conventional DGAC were used. These studies will continue until the necessary data are obtained to determine what reduction in overlay thickness is appropriate if RAC is used.

TYPES OF RAC USED BY CALTRANS

Caltrans has constructed 24 rehabilitation projects using RAC overlays. These projects are listed in Table I. These projects have included rubber modified: dense graded asphalt concrete (DGAC), open graded asphalt concrete (OGAC), gap graded asphalt concrete (GGAC), and an Arizona-type, three-layer system. These overlays have been placed over flexible pavement (AC) as well as rigid pavement (PCC). On these projects, six different types of RAC have been used: Devulcanized reclaimed rubber (Flomix or Ramflex) has been added to conventional DGAC mix; vulcanized reclaimed rubber has been added to a gap-graded aggregate and conventional asphalt (PlusRide - a patented mix), and vulcanized reclaimed rubber has been preblended with a conventional asphalt to form asphalt-rubber binder (Arm-R-Shield or Overflex - patented binders), which was then added to a dense graded, open graded or gap graded aggregate (known as asphalt-rubber hot mix gap graded, ARHM-GG) or the binder was used with a pre-coated chip as a stress absorbing membrane interlayer (SAMI) in an Arizona-type, three-layer system. SAMIs also have been used with other RAC mixes.

OVERLAY DESIGN

Caltrans uses a deflection-based design procedure for rehabilitation of flexible pavements. This procedure is also used for RAC overlays. On the early RAC projects, the RAC overlay design thickness was the same as that provided from the deflection study for conventional DGAC. Now Caltrans is experimenting with reduced thickness RAC overlays (as compared to the conventional AC design thickness). The design life normally used is ten years, and during this time only minor maintenance is expected.

A different approach is used for PCC pavement rehabilitation involving DGAC overlays. In order to try and obtain the desired ten-year design life, the early approach (prior to 1982) was to place a DGAC overlay 0.25 to 0.50 foot in thickness depending on the condition of the existing PCC pavement. However, the ten-year design life was not being achieved. After 1983, this strategy changed. PCC pavements are now cracked and seated, a leveling course of DGAC is placed, a pavement reinforcing fabric (PRF) is placed, and finally the pavement is overlayed with DGAC 0.25 thick placed in two lifts. This same approach is used for RAC overlays over PCC pavements. The RAC would replace the DGAC overlay over the PRF. In this particular case, the RAC thickness would be reduced.

MIX DESIGN

The Hveem mix design is used by Caltrans for all RAC mixes with a few minor changes. The mix and compaction temperature is increased from 230°F to 300°F and the Hveem stability requirement is waived. However, stability is still considered during mix design for DGAC mixes utilizing

TABLE 1

RUBBERIZED ASPHALT CONCRETE PROJECTS PLACED IN CALIFORNIA

	PROJECT	CLIMATIC ³ REGION	CONST. DATE	DISTRICT COUNTY ROUTE	POST MILE LIMITS	STRUCTURAL ¹ SECTION (FT)	AADT ² (% TRUCKS)
t.	Meyers	s	1978	03-Ed-50	72.45/72.50	0.20 Flo	17,300 (3.1)
2.	Strawberry	S	1980	03-ED-50	52.2/66.5	0.10 ARC/0.20 AC/PRF	12,100 (3.1)
3.	Donner Summit	s	1980	03-Nev-80	5.16/5.59	0.20 ARC/0.40 AC	26,500 (9.0)
4.	Donner Lake	s	1981	03-Nev-80	7.3/8.8	0.20 ARC/PRF/LEV	26,500 (9.0)
5.	Boca	s	1982	03-Nev-80	23.8/24.8	0.10 & 0.20 ARC/0.10 OGAC (R)	21,400 (16.1)
6.	1-80/Rt 20 Jct.	s	1982	03-Nev-20	44.1/44.3	0.08 OGAC (R)	2,700 (8.0)
7.	Ravendale	S	1983	02-Las-395	92.0/101:4	0.15 ARC & Plus 0.15 & 0.25 ARC & Plus/SAMI (R)	1,200 (22.3)
8.	Colfax	S	1984	03-Pla-80	35.0/36.9	0.15 ARC/PRF/LEV	25,500 (14.2)
g.	Flouriston	s	1984	03-NEV-80	23.5/28.0	0.25 RAMPRF/LEV	21,400 (16.1)
10.	Monte Vista	s	1984	03-PLA-80	42.9/45.7	0.25 RAM/PRF/LEV	25,500 (14.2)
11.	So. Lake Tahoe	s	1985	03-ED-89	8.6/10.0	0.17 ARC/PRF/LEV	17,800 (4.1)
12.	Pittsburg	С	1985	04-CC-4	16.8/18.8	0.10 OGAC/SAMI (R)/0.10 OGAC	90,000 (5.7)
†3.	White Cloud	S	1986	03-NEV-20	28.3/29.2	0.10 Plus	2,700 (9.8)
†4.	Hayward	С	1986	04-Ala-880	13.7/15.0	0.08 OGAC (R)	175,000 (8.2)
15.	Elkhorn RSR ⁴ .	V	1987	03-Sac-5	34.0	0.10 ARC	N/A
16.	Ludiow	D	1987- 88	08-SBd-40	80.4/140.0	0.20 & 0.30ARC & Plus	11,200 (51.9)
17.	Goldrun	s	1988	03-Pla-80	38.3/42.9	0.20 & 0.30ARC & Plus/PRF/LEV	25,500 (14.2)
18.	San Francisco	C	1988	04-SF-101	0.0/3.0	0.08 OGAC (R)	260,000 (4.1)
19.	Pit River Bridge	٧	1989	02-Sha-5	28.1/28.8	0.10 ARC	17,000 (28.9)
20.	Antler Undercrossing	V	1989	02-Sha-5	41.05	0.10 ARC	15,400 (31.9)
21.	Chico	٧	1990	03-But-32	18.58/18.71	0.10 ARHM-GG	1,500 (11.8)
22.	Tulelake	S	1991	02-Mod-139	41.1/50.5	0.15 & 0.25 ARC/SAMI(R)	3,100 (13.6)
23.	Running Springs	s	1991	08-SBd-18	31.6/36.7	0.25 ARC & 0.20 ARHM-GG	8,000 (11.3)
24.	Los Banos	V	1991	10-Mer-5	3.03/3.50	0.10 OGAC/SAMI(R)/LEV	24,700 (29.8)

Motes:

- 1. FLO = Flomix ARC = Asphalt-Rubber Concrete
 - PRF = Pavement Reinforcing Fabric

 - LEV = Conventional DGAC Levling Course
 OGAC (R) = Open Graded Asphalt Concrete using
 Asphalt-Rubber Binder.
 - Plus = PlusRide
 - SAMI (R) = Stress Absorbing Membrane Interlayer using Asphalt-Rubber Binder.
 - RAM Ramilex

- ARHM-GG = Asphalt-Rubber Hot Mix Gap Graded AC = Asphalt Concrete
 - 2. AADT = Average Annual Daily Traffic in 1990.
 - 3. S = Snow Region Tire Chains Used
 - C = Coastal Region
 - V = Valley Region
 - D = Desert Region
 - 4. RSR = Roadside Rest.

asphalt-rubber, with a lower value of around 20 being a target minimum. Void content and flushing on the surface of the fabricated briquettes are the primary concerns for mix design. The Caltrans 3/4 inch maximum, medium. Type B, grading is normally used for the dense graded RAC test sections. The binder content for open and dense graded RAC mixes is usually about 20% higher than that for the conventional DGAC mixes. The binder content for gap-graded RAC mixes can be even higher, around 40% higher than that for the conventional DGAC mixes. The void content now used in the design for RAC mixes usually runs between 3.0 to 4.0% based on a calculated theoretical maximum density. For gap graded mixes using asphalt-rubber binder, the optimum asphalt content is determined strictly on void content.

COST ANALYSIS

The cost per ton of RAC, depending on the type, runs 40% to 100% over that of conventional DGAC. Most of the RAC projects constructed by Caltrans in the past have involved fairly low tonnages of RAC and, as a result, the cost has been relatively high. It is believed that as the use of RAC increases, a reduction in cost will be realized. However, even at the higher cost, RAC can be cost effective if proportionally reduced thicknesses (when compared to conventional DGAC) will provide the desired service life.

CONSTRUCTION

The construction of RAC overlays by Caltrans has been similar to that of conventional AC overlays, although there are a few important differences. First, these mixes must be placed at a higher temperature, preferably in a range between 300°F and 325°F. Raking should be completed before the mix temperature drops below 290°F. As the mix cools, it becomes stiffer and raking becomes very difficult. Pneumatic tired rollers should not be used to compact RAC mixes because the pneumatic tires stick to the rubber particles in the surface of the matt and tear it up during rolling. Breakdown rolling should be completed before the mix drops below 290°F. If the mix is compacted at 290°F or above, excellent relative compaction has usually been achieved quite easily. Values of 96% to 98% relative compaction (compared to a laboratory compacted briquette) are quite common.

RAC LICENSE AND PATENT CHANGES

Over the years, there have been some major and minor changes concerning the ownership and use of the various RAC products. In the late 1970's, Flomix (produced and sold by U.S. Rubber Reclaiming, Inc.) was changed, reportedly in name only, to Ramflex. Ramflex was not only used as a dry rubber additive to conventional DGAC, but it was also reportedly used in the patented, asphalt-rubber binder, Arm-R-Shield, sold by Arizona Refining Company. In the middle 1980's, Caltrans was told that Arizona Refining did not use Ramflex and had not been using it since 1980, even though Arizona Refining had promoted their binder as being superior to Overflex (the

patented asphalt-rubber binder sold by Crafco) because Arm-R-Shield utilized devulcanized rubber. There was concern at that time whether or not the formula had actually changed and whether the performance would also change. U.S. Rubber Reclaiming was sold a few years ago and Ramílex is no longer available.

In 1984, International Surfacing Inc. (ISI) came into existence under Crafco Inc. They (ISI) marketed strictly the Overflex binder. The next year, 1985, Arizona Refining was sold to Edgington Oil, who in turn sold the patents for Arm-R-Shield to Crafco. Crafco then owned all the patents for asphalt-rubber binder. This concerned Caltrans because of the elimination of competitive bidding. Crafco became aware that this created a problem for future asphalt-rubber usage so, in 1986, Crafco made arrangements with at least three other companies in the western United States to market the Arm-R-Shield binder. Manhole Adjusting Inc. (MA) was the company chosen to market this binder in California. Prior to 1988, their (MA) involvement was strictly with seal coats. For the last four years, MA has been using Arm-R-Shield in a relatively new RAC mix. It is an asphalt-rubber hot mix using a gap grading for the aggregate (ARHM-GG). ISI has also been marketing this type of mix using the Overflex binder.

In 1982 PlusRide Inc., who was licensed to sell PlusRide in the U.S.A., was sold to Pavetech Inc. (a group of investors) and the product was sold under the All Seasons Surfacing Company name. In recent years, Pavetech purchased the patent for PlusRide and has been marketing it under the Pavetech name.

With all the changes mentioned above, Caltrans has been concerned as to what effect these changes have had on the products themselves. The main concern today involves the difference in the two asphalt-rubber binders. In most of the early projects (Numbers 2,3,4,5,6,7,8 and 11 in Table I), the Arm-R-Shield binder was used. During this period, the Overflex binder was used strictly in seal coats. In 1985 this usage was reversed (in conjunction with the changes mentioned earlier). For the later projects (Numbers 12, 14, 15, 16, 17, 18, 19, 20 and 22 in Table I) the Overflex binder was used. The first DGAC project using Overflex was not constructed until 1987; thus, our experience with this binder in DGAC covers only four years. It is not known whether the long-term experience will be the same using the Overflex binder in DGAC. As mentioned earlier, the most recent usage of Arm-R-Shield has been with ARHM-GG and this experience spans only four years. Overall, the patented binders have been produced for more than fifteen years; thus, the binders alone would not be considered experimental. It is the usage of the binders with different aggregate gradings (i.e., RAC mixes) that is considered experimental by Caltrans.

EVALUATION OF RAC PROJECTS

Caltrans experience with RAC far exceeds that of any other state in the United States. Even though this experience dates back 13 years, the

evaluation of RAC mixes must be divided into two phases. The first phase would include the early projects where equal thicknesses of RAC and conventional DGAC were compared. This experience includes all the DGAC projects constructed up to 1987 with the exception of the Ravendale Project (No. 7 in Table I). (The Ravendale Project started the second phase.) Based on the results obtained on the Ravendale Project after about three years, it became evident that thinner structural sections of RAC could outperform thicker sections of conventional DGAC. All projects after 1986 involved reduced thicknesses of RAC (compared to the design thickness for the conventional DGAC mix).

All projects constructed by Caltrans were reviewed in 1991, and the project files also were reviewed. The Appendix contains observations for each type of RAC and specifically each project where it was used. A matrix showing the types of mixes used, number of projects, etc. is shown in Table II.

TABLE II

RAC¹ MATRIX

	·	Type of RAC					
		Fiomix/Ramflex	Arm-R-Shield	Overflex	PlusRide		
Numb	er of Projects	3	10	10	4		
	d Over PCC	2	4	42	1		
	d Over AC	1	6	5	3		
Туре	Dense Graded	3 (1, 9, 10) ³	8 (2, 3, 4, 5, 7, 8, 11,23)	6 (15, 16, 17, 19, 20,22)	N/A		
of	Open Graded	0	1 (6)	4 ⁴ (12, 14, 18,24)	N/A		
Mix	Gap Graded	0	2 (21,23)	0	4 (7, 13, 16, 17)		
Oldes	t Project	13 yrs	11 yrs	6 yrs	8 yrs		

Notes:

- 1. RAC = Rubberized Asphalt Concrete.
- 2. Includes 2 bridge decks.
- 3. Numbers in () represent projects listed in Table I.
- 4. On Projects 12 and 24 conventional OGAC was used over a SAMI(R) over conventional OGAC or DGAC (Arizona-Type 3 Layer System).

There has been some laboratory analysis of mixes used on Caltrans projects, but this work has been limited. Caltrans is presently looking into possible laboratory tests which might be applicable for the evaluation of RAC mixes in a laboratory research effort.

PERFORMANCE SUMMARY OF RAC (IN CALIFORNIA)

Flomix/Ramflex (DGAC): There have been three projects constructed using this rubber additive and the mix has not been considered cost-effective on any of these projects.

<u>Arm-R-Shield (DGAC)</u>: There have been six projects constructed using equal thickness RAC and two using reduced thickness RAC of this type. Three have been considered not cost-effective, two cost-effective, and the other three are too new to determine cost-effectiveness. Even though the RAC outperformed the conventional DGAC on the two projects considered not cost-effective, the benefits did not appear to override the initial higher cost of the RAC.

Arm-R-Shield (OGAC): There has been one project constructed using this OGAC(R). The use of OGAC(R) on this project indicates that it may be cost-effective because it allowed an OGAC mix to be used successfully in the snow country where conventional OGAC has not normally performed well. However, additional projects should be constructed in a freeze-thaw region.

Arm-R-Shield (GGAC): There have been two projects constructed using ARHM-GG with the oldest project being just over one year old. More laboratory research is necessary to provide a formal mix design for this type of RAC and more field performance data, including long-term observations, are needed. However, based on four years of experience in Arizona and various cities and counties in California (non-Caltrans projects) it has been shown to be extremely effective for mitigation of reflective cracking.

Overflex (DGAC): There have been six projects placed using this type of RAC. All these projects used reduced thickness RAC. The use of this mix has been considered cost effective on only one of the projects with the other five being too new to determine cost-effectiveness. On two of these projects, RAC has been used as a thin overlay strategy for bridge deck rehabilitation.

Overflex (OGAC): There have been two projects constructed using this OGAC(R). The thickness was reduced on these projects to help offset the initial cost. The use of OGAC(R) on both of these projects allowed an OGAC mix to be placed successfully in a climatic area where it normally could not be placed under current specifications. Also, it has been shown by experience in Arizona that OGAC(R) will perform as long or longer than conventional OGAC. Therefore, it appears that the use of OGAC(R) on these projects will be cost-effective.

Overflex (Three-Layer System): There have been two projects constructed using an Arizona-type, three-layer system. These projects are performing very well, but it is too early to determine if the use of these three-layer systems are cost-effective.

<u>PlusRide (GGAC)</u>: There have been four projects constructed using PlusRide RAC. Its use has been determined to be cost-effective on one project and it is too early to determine the cost-effectiveness on two other projects. The fourth project is not being considered in the evaluation of the PlusRide RAC because it was not properly designed.

SUMMARY

From our experience, it has been learned that when compared to conventional DGAC, RAC can tolerate higher deflections. The RAC has lower permeabilities which in turn decreases oxidation and aging. These mixes have also proven to be more abrasion resistant in snow regions and, when distress does develop, it progresses at a much slower rate. All these desirable qualities that RAC mixes possess can lead to decreased maintenance costs and ultimately could lead to lower annual equivalent costs when compared to conventional DGAC.

Overall, when RAC (DGAC) has been compared to an equal thickness of conventional DGAC, it has usually outperformed the DGAC by exhibiting less distress and requiring less maintenance. Unfortunately, these positive benefits have not always been enough to offset the 40-100% increase in cost over conventional mix. However, it has been shown on more than one project that reduced thickness RAC can outperform thicker conventional DGAC mixes. The question that arises is how does Caltrans determine the correct thickness or type of RAC to use on a particular project to obtain a certain design (service) life?

From the Ravendale experience (No. 7 in Table I), we have learned that a 50% reduction in overlay thickness can result in equivalent service life when using RAC. With this reduction in thickness, the RAC has also shown to be extremely cost-effective. However, is this 50% reduction applicable to other climates as well? Can this 50% reduction be utilized at locations where thinner conventional DGAC thicknesses such as 0.40, 0.30 or 0.20 foot would be used? Will this 50% reduction hold true for overlays over PCC as well? Should a 30% reduction be used as a more conservative figure? What kind of reduction can be tolerated when using ARHM-GG? Will ARHM-GG outperform other types of RAC? There are many questions to be answered, but this will take time. Are we willing to make guesses routinely and hope to get our ten-year design life? If our guesses are wrong, it would be very costly. At this point in time, we are doing just that, guessing; but, these guesses are being made on selected experimental projects.

Based on experience in Arizona and cities and counties in California (non-Caltrans projects), ARHM-GG has shown it can be very effective for the mitigation of reflective cracking. ARHM-GG has been placed over badly alligator cracked pavements in Southern California which encounter extremely high truck traffic and it has performed very well. Even though these projects are only a few years old, the ARHM-GG is exhibiting no

distress. Based on this experience, it is believed that this type of RAC should retard reflective cracking for a normal design life (10 years) under normal traffic. For this reason Caltrans is working with the FHWA to remove the experimental classification for use of ARHM-GG for mitigation of reflective cracking. (This would not include structurally inadequate pavements requiring thick overlays.)

We need to move forward more quickly with the evaluation of RAC mixes. Based on our experience from the Ravendale project (No. 7 in Table I), by using reduced thickness test sections we can hopefully obtain data more quickly. We will continue to work closely with the RAC industry on all projects which include RAC mixes. We need to construct a minimum of ten projects around the state as soon as possible to help expedite the evaluation of the various types of RAC mixes for structural equivalency. Each project should contain the recommended design thickness and various reduced thicknesses of conventional DGAC. It also should contain at least two types of RAC and at least two thicknesses of each type of RAC. SAMIs should also be used on all RAC projects. The data obtained from projects of this nature and the data obtained from laboratory research should provide sufficient information to cut the evaluation period to approximately a five-year span. At that time, some type of recommendation for routine usage of RAC for structurally inadequate pavements should be expected.

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DISCLAIMER

The contents of this paper do not necessarily reflect the official views or policies of either the Federal Highway Administration or the State of California. They reflect the views of the author, who is responsible for the facts and accuracy of the data presented herein. Also, neither the State of California nor the United States Government endorse products or manufacturers. Trade and manufacturers names are presented herein because they are considered essential to the objective of this paper.

L-cracks and surface abrasion with some raveling at the longitudinal joints at the lane lines. The rich control mix had required some patching and exhibited some rutting. Both mixes have required very little maintenance overall with the majority of this being crack sealing. This project was rehabilitated in 1991. The RAC performed slightly better than the control, but the use of RAC on this project probably was not cost-effective because the cost of the rich control mix was less than that of the RAC. However, at a lower elevation the rich control mix would probably have rutted much sooner.

Project 5 - This project is nine years old. There were various test sections compared to a 0.35 foot conventional DGAC control section. The two RAC sections were 0.10 and 0.20 foot thick over a 0.10 foot thick conventional OGAC. All sections are now exhibiting T-cracks, L-cracks, and surface abrasion with some maintenance patches; but the 0.20 foot RAC over 0.10 OGAC(R) is showing less distress than all other sections. This project is ready for major rehabilitation. On this project the use of RAC does not appear to have been cost-effective.

Project 7 - This project is eight years old and was publicized nationally in a 1988 TRB paper (Reference No. 4). This was the first reduced thickness RAC project involving an overlay of AC pavement. On this project (13 different test sections) different thicknesses of RAC with and without a SAMI were compared to different thicknesses of conventional DGAC (0.18 to 0.52 foot actual thickness). The thin sections of DGAC all failed within the first two years. In early 1991 the 0.52 foot DGAC control section was exhibiting intermittent to continuous T-cracks, L-cracks, block cracking, and surface abrasion and a chip seal was placed on this section in late 1991. When most of the sections were placed on this project it was believed that there was a likelihood that a ten-year service life would not be achieved because of the thin sections used; however, the RAC sections have required little to no maintenance and are still performing today. The RAC sections are now exhibiting some T-cracks, L-cracks, surface abrasion and raveling. The use of RAC on this project is considered to have been extremely costeffective.

Project 8 - This project is seven years old. There was no control section placed on this project. The RAC on this project developed T-cracks after only two years. The RAC now exhibits T-cracks every 15 to 50 feet, surface abrasion, and some raveled areas. A slurry seal was placed on the first 0.3 mile of the project after three years (1987). There has been very little maintenance required on the rest of the project. It is too early to determine the cost-effectiveness of RAC on this project.

Project 1I - This project is six years old. There was no control section placed on this project. The RAC on this project developed T-cracks after only two years. The RAC is now exhibiting intermittent T-cracks, some L-cracks, surface abrasion and some raveling. One 100-foot section (single lane width) has been replaced with conventional DGAC. This project

APPENDIX

EVALUATION OF RAC PROJECTS

The project numbers listed below represent projects in Table I and II.

<u>Flomix/Ramflex (DGAC</u>: Project 1 - This project is 13 years old. Both the RAC and the conventional DGAC control sections (equal thicknesses) have performed quite similar. They both exhibit the same type and degree of cracking. The use of Flomix on this project was not cost-effective. This project is ready for major rehabilitation.

Projects 9 and 10 - These two projects are seven years old. Both of these projects exhibited distress in the form of transverse cracks (T-cracks), longitudinal cracks (L-cracks) and raveling within the first two years. The distress has increased since then with extensive maintenance required on these projects in the last three years. The conventional DGAC control sections (equal thickness) have performed better than the RAC and have required less maintenance. The use of Ramflex on these projects was not cost-effective. These projects are ready for major rehabilitation.

Arm-R-Shield (DGAC): Project 2 - This project is 11 years old. On this project a 0.30 foot overlay was placed over pavement reinforcing fabric (PRF) with the top 0.10 foot being RAC. There are considerable T-cracks, L-cracks and raveling existing on this project. There have been chip seals, slurry seals and some maintenance blankets placed. The conventional DGAC control section (0.30 foot thick) has performed quite well considering that the average life before major maintenance is required is usually four to six years in this region. The RAC section performed only slightly better over the years, requiring less maintenance in the early years. This project is ready for major rehabilitation. The use of RAC on this project was probably not cost-effective; however, this is difficult to determine because the control section was quite small and may not have been representative for the whole project.

Project 3 - This project is 11 years old and the RAC used has performed extremely well. It is a truck climbing lane about one-half mile in length. It now exhibits extensive T-cracks, L-cracks and surface abrasion and is ready for major rehabilitation. A conventional AC overlay in this area $(7000\pm$ foot elevation with extensive chain wear during the winter) would normally require an overlay or replacement within five years. The RAC on this project required very little maintenance. The use of RAC on this project was cost-effective.

Project 4 - This project is ten years old. It is on a slight grade and is in the same area as Project 3. The control section was a conventional DGAC mix (equal thickness) with an asphalt content 0.4% above the normal optimum bitumen content (OBC). Both the RAC and control mixes have performed very well on this project. In early 1991 they exhibited extensive T-cracks,

It appears that the conventional DGAC design was not appropriate. It is too early to determine if the RAC is cost-effective on this project.

Project 17 - This project is three years old. On this project two reduced thicknesses of RAC were compared to a conventional DGAC control section. T-cracks and some raveled areas appeared in the RAC sections within one year. The RAC sections are now exhibiting intermittent T-cracks and some raveled areas throughout most of the project. The control section has only a few T-cracks. All sections are exhibiting surface abrasion due to the tire chain wear. The control section is also showing some flushing and bleeding in the wheel tracks. This control mix was probably overasphalted. This may be the reason for the small amount of T-cracks. The reduced thickness RAC (0.20 foot) was placed in two equal lifts (using 3/4 inch maximum aggregate). During compaction of these lifts, aggregate was broken on the surface. This is probably the reason for many of the severe raveled areas in this section. The RAC on this project was placed over a continuously reinforced concrete pavement which could not be cracked and seated and this is probably why the T-cracks appeared so soon on this project. It is too early to determine if RAC is cost-effective on this project.

Projects 19 and 20 - Both of these projects are bridge decks and are only two years old. A thin 0.10 foot lift of RAC was used to determine if it would provide a cost-effective bridge deck rehabilitation strategy. Within the first year each deck exhibited one small raveled spot which has been removed and replaced with conventional DGAC. In the second year, a few areas exhibited alligator cracking. It is too early to determine if RAC is cost-effective on these projects.

Project 22 - This project is only four months old and no conclusions can be made at this time.

Overflex (OGAC): Projects 14 and 18 - These two projects are five and three years old respectively. Night construction is required in the San Francisco Bay area due to traffic volumes during the day, and temperature conditions at night restrict the placement of conventional OGAC in some locations. OGAC(R) can be mixed at a higher temperature and, therefore, placed at a lower ambient temperature. The thickness of the OGAC(R) was reduced 20% to help offset the higher initial cost. By using OGAC(R) on these projects, it allowed the successful placement of an open graded mix in an area where it normally could not be placed. For this reason, the use of OGAC(R) on these projects is considered to be cost-effective.

Overflex (3-Layer System): Project 12 - This project is six years old and is the first time Caltrans has used an Arizona-type, three-layer system. At this time there is no distress on the project. It is performing quite well and it appears this strategy will be cost-effective.

Project 24 - This project is only seven months old and no conclusions can be made at this time.

required some maintenance patching in 1991. It is too early to determine the cost-effectiveness of RAC on this project.

Project 23 - This project is only five months old. No conclusions can be made at this time.

Arm-R-Shield (OGAC): Project 6 - This project is nine years old. Conventional OGAC is not used in the snow regions because of the freeze-thaw and tire chain action and a lack of resistance to snow plows. The OGAC(R) on this project now shows signs of surface abrasion and some portions have been removed by snow plows. The majority of the material removed by snow plows has taken place in the last three years (on the high side of the superelevation). This project is on a curve and a slight grade. These results indicate that OGAC(R) may be cost-effective in a freeze-thaw snow region over AC pavement. The use of OGAC(R) should be tried on additional projects in a freeze-thaw region. The use of OGAC(R) on this project was cost-effective.

Arm-R-Shield (GGAC): Project 21 - This project is only one year old. ARHM-GG was placed for the first time by Caltrans on this project. This project was funded under the SHRP Program. A standard mix design procedure for this type of RAC mix has not been formalized at this time. More laboratory research is necessary to formalize a procedure. The mix design decisions were made by the contractor on this project, and the mix was placed without any major problems.

Project 23 - This project was mentioned under Arm-R-Shield (DGAC). No conclusions can be made at this time.

Overflex (DGAC): Project 15 - This project is four years old. The roadside rest (RSR) on this project was to be reconstructed around 1991 but the existing pavement was badly cracked. In the hopes of obtaining four years of surface life, a thin lift of RAC was used. The RAC is now showing signs of reflective cracking, but it appears that the thin RAC will accomplish its task of holding the underlying pavement intact until the time of reconstruction. Based on past experience, a conventional DGAC thin overlay would not have accomplished this. The use of RAC was cost-effective on this project.

Project 16 - This project is four years old. It is the first time RAC has been used in a desert climate by Caltrans. Two different thicknesses of RAC, one equal and one reduced thickness, were compared to two conventional DGAC control sections. Within one year, the reduced thickness RAC section and the control sections exhibited T-cracks and some L-cracks. Now the cracking is intermittent to continuous in these sections with some alligator cracking also existing. The distress in the equal thickness RAC section is very minor and consists of only a few T-cracks and one raveled area. Up to this point, the reduced thickness RAC section has performed equally to the control sections, and the equal RAC section has outperformed the control sections. However, it is not known as to the reason(s) for the early cracking.

<u>PlusRide (GGAC)</u>: Project 7 - This project was mentioned earlier under Overflex (DGAC). PlusRide was also placed in different thicknesses with and without a SAMI. The PlusRide sections exhibited some potholing after only a few years but have performed quite well compared to the thick conventional DGAC control section (0.52 foot thick). The PlusRide sections are exhibiting T-cracks, L-cracks, block cracks, some alligator cracks, surface abrasions and raveling. Some of the thicker Plusride section (0.2 miles) required a maintenance overlay. The use of PlusRide on the project was cost-effective.

Project 13 - This project is five years old. On this project PlusRide was used in a 0.10 foot maintenance blanket and was compared to a conventional DGAC blanket of equal thickness. Unfortunately, there was no mix design provided by the PlusRide consultant and the mix was very likely underasphalted. A portion at the end of the PlusRide section raveled after the first year and required an overlay of conventional DGAC. After two years a chip seal was placed on another portion of the PlusRide section. However, some of the remaining PlusRide section is still performing quite well, with less distress than the control. This project was placed at the same time that Pavetech had just purchased PlusRide Inc. and they would not provide any on-site assistance. Because this PlusRide mix was not designed properly, this project is not being considered for evaluation purposes (only for information).

Project 16 - This project is three years old. This project was mentioned earlier under Overflex (DGAC). Plusride was also placed on this project in two different thicknesses, a reduced and equal thickness. The equal thickness section developed bleeding areas within the first year and they have become larger and more severe since then. The PlusRide is potholing and raveling in one location in this section. The reduced thickness section has some small intermittent traverse humps in the surface (appearing during construction due to expansion of crack sealant) and a few flushing spots in the wheel tracks but no cracking. As mentioned earlier, the control sections are exhibiting a considerable amount of cracking. The reduced PlusRide section is performing very well, but it is too early to determine if PlusRide is cost-effective on this project.

Project 17 - This project is three years old. This project was mentioned earlier under Overflex (DGAC). The PlusRide was also placed on the project in two reduced thicknesses. The PlusRide sections are exhibiting very little surface abrasion, some flushing in the wheel tracks at a few locations, a few potholes and a few T-cracks. This is the only distress noted at this time. Overall the PlusRide is performing very well, but it is too early to determine its cost-effectiveness.

RAC EXPERIENCE BY OTHERS

As mentioned earlier, the experience by others using RAC in general is very limited; however, this does not mean that there have not been any projects constructed elsewhere. More than 20 states have constructed at least one project using RAC. Unfortunately, the data on many of these projects are inconclusive regarding cost-effectiveness.

PlusRide has been used by a number of states with Alaska probably having the most experience. Because of Alaska's positive experience with PlusRide, they presented a proposal to the FHWA to have it removed from the experimental category. The proposal was rejected by the FHWA because of insufficient backup data. The experience by other states has been mixed, some good and some bad.

More states are beginning to use asphalt-rubber in DGAC, but most of this experience is limited to one to three years. There are more than five states known to have projects that are older than four years, but there is no conclusive data available as to the cost-effectiveness of RAC based on our information.

ARHM-GG has been promoted quite heavily around the U.S.A. and especially in the southern California area in the past three years. There have been more than 20 projects constructed during this time, with most being only one or two years old. Experience to date has been <u>very</u> positive with this type of RAC. At this time it is impossible to draw any long-term conclusions from the use of ARHM-GG since the experience with successful projects dates back only three years. But, based on this experience it has shown to be very effective for the mitigation of reflective cracking.

OGAC(R) has been used by a few states with Arizona having more than ten years experience. It has performed very well on a number of projects in different states based on Caltrans information.

Three-layer systems have also been used by Arizona and for more than ten years. They have been used very successfully in that state. In 1985, Arizona started using the three-layer system non-experimentally. Caltrans has additional three-layer test sections scheduled for construction in 1992.